Aspects of Pesticidal use of Toxaphene and Strobane on Man and the Environment

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Special Working Group on Toxaphene and Strobane

Chapter I William V. Hartwell, Ph.D.

Chapter II Padma R. Datta, Ph.D.

Chapter III Merle Markley

Chapter IV Jacob Wolff (retired)

Chapter V Economic Evaluation Branch, C&D, OPP,
Arnold Aspelin, Ph.D., Chief

Chapter VI Samuel C. Billings (retired)

Edited by: William V. Hartwell, Ph.D. (Group Leader)

Library Assistance of:

Mr. Robert Cedar
Mrs. Claudia Lewis

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SUMMARY

Toxaphene and Strobane are chlorinated camphenes which are prepared from raw materials derived from different sources. Alpha pinene obtained from pine stumps is the starting material for preparing toxaphene whereas the terpene faction from other sources is used as starting material for Strobane.

These chlorinated terpenes have been widely used to control a variety of insects which occur on cotton, small grain, corn and sorghum, field and seed, other field crops, vegetables, and livestock. Available records indicate that Strobane has not been manufactured since the 1969-1970 season.

Toxaphene is more toxic than DDT in laboratory animals but less toxic than Endrin, aldrin/dieldrin or heptachlor.

Aquatic organims are highly sensitive to toxaphene but extensive fish kills have not been reported from its use. Because of this high sensitivity toxaphene has been used as a piscicide for trash fish. However, this use is no longer allowed due to the adverse effects on non-target aquatic species.

Routine monitoring studies of water from the major watersheds of the United States have not indicated the presence of toxaphene.

Since 1970 use of toxaphene has increased. This increase in use may be attributed to the need for relatively persistent pesticides to control pests on cotton following cancellation of DDT. Unlike endrin, major fish kills have not been reported from this increase.

INTRODUCTION

Toxaphene and Strobane are prepared by the chlorination of camphenes. Starting material for toxaphene is primarily of alpha pinene, whereas starting material for Strobane containes a mixture of terpenes.

Toxaphene has been used as a pesticide since 1947. Prior to that date initial patents for toxaphene had been issued to Hercules, Incorporated, which has been the major U.S. producer. When patent rights expired in the middle 1960's several companies began producing substances identical to toxaphene. Among these companies is Tenneco Chemicals, Inc. which produced Strobane. The product which Tenneco sells today is identical to toxaphene and is called Strobane-T; Strobane has not been manufactured since 1970.

Available information indicates that the amount of toxaphene used in 1973 was 128 percent of the amount used in 1970 and that this amount was 125 percent of the amount used in 1969. Comparable data are not available for Strobane-T; however, it is reasonable to believe that the estimates presented for toxaphene describe Strobane-T since the major use patterns of these two products are similar. At present 647 labels for these pesticides are registered by 147 applicants.

In 1973 60 percent of the toxaphene produced in this country was used on cotton; 5 percent was used on each category such as vegetables, small grains, corn/sorghum, and forage/seed crop;

10 percent on other field crops; and 10 percent on livestock. In terms of geographical distribution in 1973 28 percent was used in the Southeast - Mid-Atlantic region, 26 percent in the Mid-south; 10 percent in the Southwest, 9 percent in the Pacific - Far West, 7 percent in the Intermountain West - Midwest and less than 1 percent in the Northeast.

The pharmacological action of toxaphene is similar to that reported for other chlorinated hydrocarbon pesticides with central nervous systems being primarily affected. The effects usually occur within one hour after the exposure, and death, which usually occurs within 4 - 8 hours, may be delayed as long as 74 hours. In the intestinal tract toxaphene is absorbed more rapidly from vegetable oils than from petroleum products. Results of acute exposure with experimental animals indicate little difference in rates of absorption between sexes.

Storage equilibrium is reached within one week of continuous exposure, and quantities in fat are usually 1/4 - 1/8 of the dietary level. When feeding is stopped toxaphene levels decrease rapidly. Amounts of toxaphene excreted in cow's milk were similar to amounts found in fatty tissue - i.e., about 1/100 of the feed.

Although possible metabolites of toxaphene such as keto-toxaphene and hydroxy-toxaphene have been synthesized, evidence to support that these products are degradation products of biological processes has not been reported.

Acute oral toxicities of toxaphene in experimental animals are greater when edible fats are used as a solvent. With rats fed toxaphene in corn oil LD_{50}'s were 60 mg, and in kerosene, 190 mg per kg. In eye irritation studies 0.1/ml of a 20 percent solution of toxaphene in kerosene caused mild irritation in eyes of rabbits after 14 consecutive daily exposures, and in guinea pigs similar results were obtained with 0.05 ml. The eyes were not injured and irritation abated within 10 days after withdrawal. In subacute studies with dogs occasional stimulation of the central nervous system and degenerative changes in liver parenchyma and renal tubules were observed after 44 and 106 days of daily oral treatment with 4 mg/kg toxaphene. Available data indicate that adult goats and cattle can withstand higher doses of toxaphene than immature animals. In many instances the death observed among young calves following dipping operations with 0.75 percent toxaphene preparations made from emulsifiable concentrate was attributable to swallowing.

In chronic studies 200 ppm in diets of dogs cause liver necrosis after 4 years; with animals treated daily with twice this amount one half survived a comparable period of time. Signs of intoxication or tissue damage were not observed in monkeys treated with 0.78 mg/kg/day for two years.

No difference in reproduction, fertility, or size, viability, or anatomical structure of progeny was reported between controls and rats fed 100 ppm in diets during a three generation reproduction study. Occurrence of mutagenic effects were similar among controls and rats treated orally or interperitonealy with 180 mg per kg

toxaphene. No studies for carcinogenicity have been reported for toxaphene; however, evidence of cancer has not been detected in any of the reported chronic studies. With Strobane hepatic granulomas have been reported among rats that inhaled air for six months which contained 8.3 mg per liter of an aerosol containing Strobane. Similar results were observed in rabbits 30 days after the fourth daily treatment at the rate of 100 mg/kg with Strobane in corn oil.

The chemical structure of toxaphene has not been distinctly defined. Results of recent studies suggest that the toxaphene (and Strobane-T) probably is a mixture of at least 170 chlorinated derivatives of camphene. However, a comparison of physical, clinical, and biological assay data on toxaphene produced between 1947 and 1970 (23 years) indicate consistent uniformity of the product produced by Hercules, Incorporated during this period. For samples with known exposure to toxaphene described methodology for detection is adequate. However, lack of specificity and sensitivity of chemical methods for testing preclude positive indentification of toxaphene.

The Joint Expert Committee on Pesticide Residues reported that in 1968 an acceptable daily intake (ADI) or tolerance could not be established until additional information was obtained. Requested information included residue on plants, animals and their products (including photo-oxidation products), residues in processed vegetable oil, cereals after processing, criteria for controlling

degree of chlorination, development of comparative evaluation of regulatory analytical methods, and complete toxicological studies with standardized technical producte. At the time of this writing the official report of the Joint FAO/WHO meeting on pesticide residues in 1973 had not been issued. Present evidence suggests that an ADI cannot be established. Although FAO specifications for toxaphene have been met by one Hercules, Inc., available data may not be pertinent to toxaphene from other sources.

General tolerances of 7 ppm were allowed for fruits and vegetables under Section 408 (3469) of the Federal Food, Drug and Cosmetic Act after the 1950 Rose Hearings. Lower level tolerance resulting from petitions are 5 ppm for small grains and cotton seed, 3 ppm for bananas, 2 ppm for dry soybeans; 7 ppm in fat of meat from beef, goats, hogs, horses and sheep; 6 ppm in refined oils; and interim tolerances of 1 ppm on alfalfa and 0.05 ppm (1.25 ppm in fat) in milk. Temporary tolerances of 7 ppm are allowed on sugar beets and sunflower seeds.

Aquatic organisms are highly sensitive to toxaphene, but extensive accidental fish kills have not been reported from its use. The high toxicity to aquatic organisms including fish and some waterfowl, persistence in water, and accumulation of residues in aquatic plants and animals prompted U.S. Department of Interior to ban the use of toxaphene on Federal lands and Federal aid projects. Resistance to toxaphene has been reported in mosquitofish, green sunfish,

golden shiners, frogs, clams, crayfish and fresh water shrimp taken from water near areas of heavy prolonged use.

Toxaphene accumulates through biological process in the fat of lower aquatic members of the food web and may be passed on to higher aquatic forms following use to control trash fish. High levels of toxaphene have been detected in birds which were found dead in the areas after treatment.

Under laboratory conditions the LD_{50} for toxaphene in birds varied from 40 mg/kg to bobwhite quail to 316 mg/kg for sandhill cranes. Five day LC_{50} values for bobwhite quail is 834 ppm and 564 ppm for mallard ducklings. Decreases in populations of native birds have been observed following treatment of rangelands with toxaphene spray or bait for grasshopper control.

The susceptibility of microtine rodents to toxaphene has lead to the use of this material to control high infestations of meadow voles and other rodent pests.

Toxaphene is registered for use to control ectoparasites on livestock and residues of 7 ppm are allowed in the meats from the treated animals. Although toxaphene accumulates in the fat of animals - it decreases rapidly following removal of the exposure.

Beneficial insects are susceptible to toxaphene; however, treatment with this material does not appear to effect the eggs, has some effects on larvae, and moderate to high effects on adult forms. Use of toxaphene on legume seed crops is considered safe for honey bees since it induced less than 10 percent mortality

in bees during field tests during the bloom stage. Dust formulations are less toxic to bees than sprays.

Toxaphene has not been detected in major water sources of the United States. The relatively low level of sensitivity of analytical procedures may be the influencing factor. Toxaphene is absorbed from water onto particles of soil and organic matter and settles into the bottom sediment. Amounts in sediment have been proposed as indices of use. Toxaphene residues in pond water adjacent to areas of heavy treatment increased with use during the season.

Following applications toxaphene has been detected in air taken from areas adjacent to areas of use. Greater amounts were detected following use of dust than liquid spray.

Residues in plants are greater following treatment with water emulsions than with other preparations. With birdsfoot trefoil residues decreased from 5 ppm to 0.15 ppm 48 days after treatment. In alfalfa reduction of more than 70 percent occurred within 31 days of treatment. No obvious effects on plant metabolism have been attributed to toxaphene whereas treatment with methyl parathion may delay initiation of fruiting branches and production of floral buds.

Time required for the reduction in soil of one half the applied amount was 2.0 years for soil from Beltsville, Maryland, and 0.8 years for Mississippi and New Jersey soils.

Chapter I

Pharmacology and Toxicology of Toxaphene and Strobane

The pharmacological action and mammalian toxicity of toxaphene have been known for at least 20 years, and essential information for prevention and treatment of poisoning may be found in several commonly used references (Am. Med. Assoc., 1952; Hayes, 1963; Hercules, Inc., 1970; von Oettingen, 1963).

I.A. Pharmacology

The basic mechanism for toxicity to toxaphene has not been studied. However, due to close similarity in pharmacological actions of toxaphene and DDT it is possible an explanation of action of toxaphene would be supported by the findings with DDT. Effective use of phenobarbital and other barbiturates to treat acute poisoning from both compounds add possible substantiation for the proposed similarity of pharmacological action.

The effects caused by an acutely toxic dose of toxaphene typical of other chlorinated hydrocarbon insecticides include salivation, nausea or vomiting, hyperexcitability, tremors, spasms of back and leg muscles, chronic convulsion, and tetanic contractions of all skeletal muscles (Am. Med. Assoc., 1952; FAO/WHO, 1968; Hercules, Inc., 1970). Most of these effects are the results of diffuse stimulation of the cerebrospinal axis. With lethal

doses tetanic muscular contractions cause arrested respiration which increase in amplitude and rate as the muscles relax (McGee, et al., 1952; Negherbon, 1959). These effects usually appear within one hour after the exposure, and death, which usually occurs within 4-8 hours, may be delayed as long as 74 hours.

I.A.1. Absorption:

Toxaphene may be absorbed through the skin, lungs or intestinal mucosa. Amounts absorbed are related to the physical form and the carrier or solvent. Dermal absorption from dust is less than from sprays or oil emulsion (Lehman, 1948). In the intestinal tract toxaphene is absorbed more rapidly from digestible vegetable oils than from kerosene (Treon, et al., 1952). Results of acute exposure indicate little difference in rates of absorption between sexes of experimental animals.

I.A.2. Storage and Excretion:

Distribution and storage of toxaphene following oral and dermal exposures as studied in several species are summarized in Table I.A. Storage equilibrium is reached after one week of continuous exposure and quantities in fat usually are 1/4-1/8 of the dietary level. Thin layer chromotographic examination of extracts of fat indicate that most tissue residue was unchanged toxaphene (Dalton, 1966). When feeding was stopped, toxaphene levels in tissue decreased rapidly. Within eight weeks after stopping the feeding trials levels of toxaphene in fat of sheep

and cattle decreased to 0.5 and 3.0 ppm (Lehman, 1952; Claborn, 1956).

Table I.A.

Storage of Toxaphene in Fat Tissue After Prolonged Feeding

Species	Dietary Level	Duration	Storage Level	Method	Reference
Rat	400 ppm	2 yrs.	160 ppm	insect bioassay	Lehman, 1952
	1600 ppm	2 yrs.	205 ppm		
Dog	20 ppm	6 mos.	4.0 ppm	Org. Cl. and TLC	Hercules T105A
	20 ppm	1 yr.	4.2 ppm		
	20 ppm	2 yrs.	5.5 ppm		
	10 ppm	2 yrs.	2.3 ppm		
	5 ppm	2 yrs.	1.7 ppm		
Cattle	100 ppm	1 mos.	26 ppm	Org. Cl.	Claborn, 1956
	100 ppm	4 mos.	38 ppm		
	25 ppm	1 mo.	2 ppm		
	25 ppm	4 mos.	12 ppm		
Sheep	100 ppm	1 mo.	22 ppm	Org. Cl.	Claborn, 1956
	100 ppm	4 mos.	20 ppm		
	25 ppm	1 mo.	2 ppm		
	25 ppm	4 mos.	8 ppm		

Amounts of toxaphene excreted in cow's milk were similar to amounts found in fatty tissue (Zweig, 1963), or about 1/100 of the feed content.

I.A.3. Metabolism:

Metabolism of toxaphene has received little attention. Toxaphene is an ill-defined mixture of chlorinated camphenes which

consists of over 170 components (Cassida, et al., 1974). Attempts to introduce functional groups into toxaphene by in vitro chemical reaction have been unsuccessful, and the availability of model compounds as authentic reference standards for various separation and detection systems has been limited.

Recently, samples of "keto-toxaphene" and "hydroxy-toxaphene" were prepared by Buntin (1970). Camphor was chlorinated to a value corresponding to the addition of seven atoms of chlorine. The resulting keto-camphor, a viscous pale yellow liquid, was reduced with lithium aluminum hydride to form "hydroxy-toxaphene." These compounds are less toxic to flies and rats than toxaphene; gas chromatography shows they elute with the early peaks of toxaphene.

Cleanup techniques applied to keto-toxaphene and hydrox-toxaphene show that the former survives fuming sulfuric acid, but that hydroxy-toxaphene does not. Dehydrohalogenation (as applied to toxaphene prior to gas chromatography) showed that these compounds are retained in the alkaline aqueous phase when they are extracted with hexane. Both compounds are extracted by hexane from distilled water.

Weathered toxaphene residues from alfalfa were examined for the possible presence of keto-toxaphene. No evidence for their presence was found by Carlin (1970).

In an attempt to study the metabolism of toxaphene in the honeybee, Jumar and Sieber (1967) conducted experiments to determine residues in rape seed oil, honey and bees. They applied ^{36}Cl-tagged toxaphene to rape plants and determined that residues were transmitted to rape seed oil in the range of 0.3 to 1.5 ppm, depending on the method of application. Honey made by bees exposed to the toxaphene-treated rape plants contained less than 0.01 ppm toxaphene. The study on toxaphene in the bee employed ^{82}Br-toxaphene (one Cl atom replaced by ^{82}Br). More than 95 percent of toxaphene absorbed by bees from feeding was stored briefly in the body before release as a chlorine-containing, water-soluble compound which was not identified.

I.B. Toxicity:

Acute toxicity to toxaphene and strobane has been measured by oral, dermal, intravenous, eye, and inhalation routes of exposure.

Acute toxicity measurements by oral, dermal and intravenous routes in several species are presented in Table I.B.

Table I.B.

Acute Toxicity of Toxaphene and Strobane

Animal	Route	LD_{50} mg/kg Body Weight	Vehicle
Toxaphene*			
Rat	intravenous	13	peanut oil
Dog	intravenous	5-10	peanut oil
Mouse	oral	112	corn oil
Rat	oral	60	corn oil
Rat	oral	90	peanut oil
Rat	oral	190	kerosene
Guinea pig	oral	270	corn oil
Guinea pig	oral	365	kerosene
Dog	oral	49	corn oil
Dog	oral	250	kerosene
Cat	oral	25-40	peanut oil
Rabbit	oral	75-100	peanut oil
Rabbit	oral	250-500	kerosene
Cattle	oral	144	grain
Goat	oral	200	xylene
Sheep	oral	200	xylene
Rat	dermal	930	xylene
Rabbit	dermal	4000	dust
Rabbit	dermal	250	peanut oil
Strobane**			
Rat	oral	200	corn oil
Guinea pig	oral	250	corn oil
Dog	oral	200	corn oil

* Hercules T105A
** Negherbon, 1959

Slight variance in acute toxicity of toxaphene and strobane occurred among the various species. The toxicity of toxaphene is influenced by the solvent or vehicle used. When administered orally as a solution or emulsion, it is more toxic in a digestible vegetable oil than in an oil such as kerosene. Toxicity of toxaphene by skin absorption is much less from an inert dust than from an oily solution.

In acute dermal studies with strobane 10 percent of the skin of shaved rabbits was exposed to oil solutions which contained 0.05 - 0.25 gm. strobane. No deaths occurred within one week when corn oil, white oil, paraffin oil, Ultrasene Sonneborn #51, or debose was used as solvent. However, within 30 days 50 percent mortality occurred among animals treated with 0.1 gm, and 75 percent mortality within 34 days with 0.2 gm (Negherbon, 1959).

Administration for 14 consecutive days of a 20 percent solution of toxaphene in kerosene to the eyes of rabbits (0.01 ml) and guinea pigs (0.05 ml) caused mild irritation of the eyelids with loss of hair around the eyelid. The eye was not injured and the irritation in the eyelids was abated within 10 days (Hercules T-105A).

In acute inhalation studies 3.4 g/l of 40 percent toxaphene dust in air killed approximately one half of the exposed rats within one hour (Hercules T-105A). With strobane rats were exposed to aerosol vapors 10 seconds each 10 minutes over 8 hour periods, corresponding to continuous inhalation exposure of 20 mg strobane per cubic foot. Effects of these exposures included transient lack of desire for food without further evidence of intoxication (Negherbon, 1956).

I.C.1. Subacute oral toxicity:

Subacute studies have been made in rats, guinea pigs, dogs, cattle, sheep, rabbits, and humans with toxaphene administered by oral, dermal, and respiratory routes of exposure. Hercules (T-105A) contends that outward signs of toxicity were not observed in rats fed dietary levels of toxaphene as high as 1200 ppm for 60 days. In another study rats and guinea pigs were intubated with kerosene solutions of 5 percent toxaphene 5 days per week for 6 months at dosage rate of 6 and 48 mg/kg (approximately equivalent to 100 and 800 ppm, respectively in diet) without gross toxic effects. Ortega, et al., (1951, 1957) fed 50 and 200 ppm to small groups of rats for 9 months. At these levels no signs of toxicity occurred, and food consumption and growth rates were not inhibited. Slight changes were observed in livers from 3 to 12 rats fed 50 ppm, and distinct changes in 6 of the 12 fed 200 ppm. Increases in enzyme activity of liver microsomal enzyme of rats occurred at dietary levels of 5 ppm and above (Kinoshita, et al., 1966).

Groups of dogs received capsules of toxaphene at 4 mg/kg for 44 and 106 days. Occasional stimulation of the central nervous system occurred a short time after administration. Degenerative changes were observed in liver parenchyma and renal tubules (Lackey, 1949).

Cattle and sheep were fed diets containing toxaphene levels as high as 320 ppm for 134 and 151 days. Stimulation of central nervous system with tremors was observed in steers fed 320 ppm, but no hematological or pathological changes were noted in tissues.

I.C.2. Subacute Dermal Toxicity:

Dermal exposures at the rates of 332 mg/kg in mineral oil containing 20 percent toxaphene for 14 days were fatal to 73 percent of the rabbits tested (Hercules T-105A). When dust preparations containing 5, 40, and 50 percent toxaphene were applied to skin of rabbit at 100 mg/kg/day for 30 days and at 200, and 500 mg/kg/day for 14 days all animals survived.

Groups of 10 rabbits were exposed on each of 5 days per week for 90 days to 1-4 ml of white oil which contained 1 percent strobane. With 1 ml no deaths occurred. With 2 ml 2 deaths occurred, one after 7 treatments and one after 35. Four deaths occurred with the 4 ml treatment, one after 7, one after 22, one after 23, and 1 after 74 doses (Negherbon, 1956).

Application of a dust preparation containing 40 and 50 percent toxaphene to the skin of dogs at 200 and 500 mg/kg/day for 32 days did not cause toxic effects. Toxaphene applied in mineral oil or dimethyl phthalate at 600 mg/kg/day for 10-22 days to shaved skin of dogs did not cause toxic effects (Lackey, 1949).

Radeleff and Bushland (1950) applied toxaphene (dip and spray) to the skin of many large animals including cattle, sheep, goats,

horses, and swine. The data indicate that adult animals can withstand higher doses of toxaphene than immature animals. Adult cattle, sheep, goats, and swine tolerated repeated applications of a 2 percent spray or a single application of a 4 percent spray without observed toxic effects. Suckling calves tolerated repeated applications of sprays containing 0.75 percent toxaphene derived from emulsifiable concentrates and wettable powders; however, dipping of very young animals caused swallowing of the dip and, therefore, was approached with caution. A single application of an 8 percent spray has been fatal to suckling calves. An 8 percent dip has been fatal to sheep and goats, but not to cattle (Hercules T-105A).

Applications of cotton patches treated with toxaphene to the skin of 200 human subjects caused no primary irritation or sensitization. Application of an aerosol spray containing toxaphene to the skin of 50 human subjects daily for 30 days at a dose of 300 mg/day produced no toxic manifestations (Hercules T-102A).

I.C.3. Subacute Inhalation:

In a series of experiments with toxaphene aerosols, animals were exposed 6 hours per day 5 days each week. The mortality findings are reported in Table I.C.

Table I.C.

Subacute Inhalation Studies with Toxaphene*

Toxaphene Concentration in mg/l of Air	Form	Test Animals	Length of Test Period	Survival
0.50	mist	rats	3 weeks	no observed effects
0.20	mist	rats, rabbits	3 weeks	no observed effects
0.04	mist	rats, rabbits	3 weeks	no observed effects
0.25	dust	rats	1 week	0%
0.04	dust	rats, dogs, guinea pigs	3 months	dogs 33%; guinea pigs 80%; rats 73%
0.012	dust	rats, dogs, guinea pigs	3 months	dogs 50%; guinea pigs 100%; rats 100%
0.004	dust	rats, dogs, guinea pigs	3 months	no observed effects

*(Hercules T-105A)

Severe weight loss preceded all deaths. Hematologic and blood chemistry measurements were within normal range. Several surviving female rats exhibited slight focal hepatic cell necrosis; other gross and histopathologic findings were normal.

Fifty human volunteers inhaled 0.0004 mg/l of toxaphene mist for ten minutes per day for 15 days. There were no subjective or objective effects.

A mist containing 0.25 mg of toxaphene per liter of air was inhaled by 25 humans for thirty minutes each day for 13 days. There was no evidence of local or systemic toxic manifestation (Shelanski, 1947).

I.D. Chronic Oral Toxicity

Toxaphene has been fed daily in the diet of rats for 2 years. The highest level which produced no toxic effect was 25 ppm. The lowest level which produced slight damage to the liver was 100 ppm. Higher levels (1000, 1500, 1600 ppm) produced some signs of CNS stimulation as well as nonspecific liver pathology typical of chlorinated hydrocarbon exposure (Hercules T-105).

Fitzhugh and Nelson (1951) fed 25, 100, and 400 ppm in diets of rats for 2 years. Significant changes were observed in the livers of rats receiving 100 and 400 ppm.

Rats were fed diets containing 50 - 500 ppm strobane for 2 years. Highest daily dosage fed without gross effects was 500 ppm (Negherbon, 1959).

Toxaphene was administered daily to dogs in a dry diet for 2 years and in capsules as a solution in corn oil for 4 years. When fed at a level of 40 ppm in the dry diet for 2 years, there was slight degeneration of the liver, while at 200 ppm for 2 years, there was moderate degeneration of the liver (Treon, et al., 1952).

After administration of toxaphene by capsule to 4 dogs at a dose of 5 mg/kg/day (approximately equivalent to 200 ppm in the diet) for 1360 days (almost 4 years), there was liver necrosis. At a dose of 10 mg/kg/day to 2 dogs, one died after 33 days and the other was sacrificed after 1260 days (Hercules, T-105A). When fed to dogs at dietary levels of 5, 10, and 20 ppm for 2 years, none

of the feeding levels produced any change revealed by organ weights, gross or microscopic examination, or any of the clinical or organ function tests (Hercules T-105A).

Monkeys were administered toxaphene in their food at a concentration of 10 to 15 ppm (0.64-0.78 mg/kg/day) for 2 years. Treon, et al., (1952), found no signs of intoxication and no evidence of damage to the tissues as determined by histological examination (Hercules, T-105A).

I.E. Reproduction, Teratology, Mutagenesis, and Carcinogenesis:

A three generation reproductive study was conducted according to currently accepted protocol on rats fed 25 and 100 ppm toxaphene (Kennedy, et al., 1973). No differences between control and toxaphene treated animals were reported for reproduction performance, fertility, lactation or viability size and anatomical structure of progeny.

In dominant lethal assays conducted with 8-10 weeks old ICR/Ha Swiss mice dosages of toxaphene in the range of 3-180 mg/kg were administered by oral or intraperitoneal routes (Epstein, et al., 1972). Occurrence of mutagenic effects among the controls and the animals treated with toxaphene were similar.

No studies for carcinogenity have been reported for toxaphene. However, no evidence of carcinogenic action was reported in any of the chronic toxicity studies previously described. With strobane hepatic granulomas were reported among rats which were exposed daily for 6 months to aerosolized strobane which was admitted

into chambers of the rats at 100 gm of aerosol per 12 cubic feet. Hepatic granulomas were observed at autopsy among rabbits 30 days after the fourth daily dermal exposure to strobane in corn oil at 100 mg/kg. In rats fed diets containing 500 ppm strobane for two years, cellular infiltration was observed in all livers examined and one of four contained granuloma (Shelanski, 1955). A significant increase in hepatomas was observed in the males of strain FB6AKFI mice which survived daily oral treatments of 4.6 mg/kg strobane for two years (Innes, et al., 1969). The hepatomas which were subsequently classified as lymphomas occurred in the surviving 11 of the 18 animals started on the study two years before.

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CHAPTER II

Chemistry and Methodology of Toxaphene

The chemical structure of toxaphene is not distinctly identified. The comparison of physical, chemical data (infrared absorption, gas chromatograms) plus bioassay data with female houseflies show that toxaphene produced during 1949-1970 (23 years) is quite uniform in its properties.

Analytical methods (total chlorine spectrophotometric and gas liquid chromatography) as described in literature is satisfactory for samples with known history (Crop sprayed, feeding studies). In evaluation of residue data obtained by gas chromatography (GLC), one must examine whether the total method involved acid clean-up and partial dehydrohalogenation prior to G.L.C. The modified GLC method for toxaphene is superior to previously reported general GLC but additional improvement for specificity and sensitivity is warranted.

The monitoring data of toxaphene from environmental specimens must be carefully scrutinized for the statements of special pre-treatment of samples prior to analysis, sensitivity of the G.L.C. method and lower limits of detection based on fortified samples. Furthermore, the re-examination of the retained environmental samples by the improved GLC-clean-up method for toxaphene is highly desirable to verify previously reported residue results in the literature and

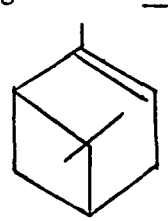
to assess the degree of persistence and/or hazards, if any, to the environment.

CHEMISTRY

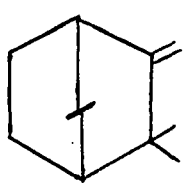
II.A. Definition, Preparation and Chemical Structure of Toxaphene

Toxaphene is defined as chlorinated camphene 67-69% chlorine. Toxaphene is prepared by chlorination of the bicyclic terpene camphene to contain 67-69% chlorine. This material has the empirical formula $C_{10}H_{10}Cl_8$. Chlorination-grade camphene is prepared by the isomerization of α-pinene, a product derived from the Southern pine tree. Some tricyclene may accompany the camphene, but less than 5% other terpenes are present. The structures of some of these terpenes are shown in Figure 1.

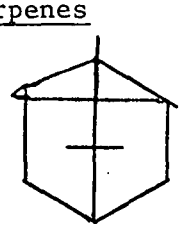
Figure 1. Structure of Some of these Terpenes



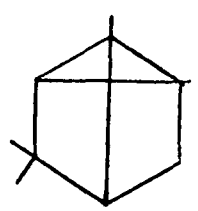
(I) α-Pinene



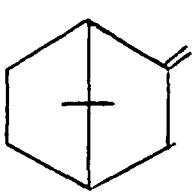
(II) Camphene



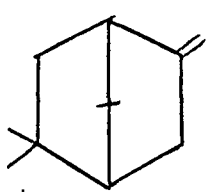
(III) Tricyclene



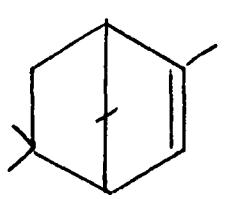
(IV) Cyclofenchene



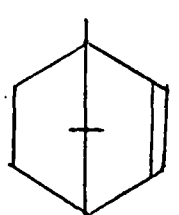
(V) α-fenchene



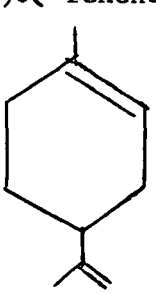
(VI) β-fenchene



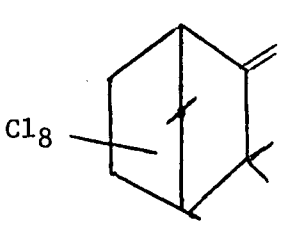
(VII) γ-fenchene



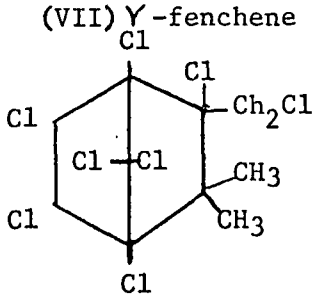
(VIII) Bornylene



(IX) Dibentene



(X) Toxaphene



(XI) Toxaphene (Messing).

The structure X is generally used to identify the chemical toxaphene. The only published chemical structure that is more detailed than X is that suggested by Messing (1956), who proposed structure XI, though apparently with qualifications (Donev and Nikolov (1965), Nikolov and Donev, (1965)).

II.B. Physical and Chemical Properties of Toxaphene.

Toxaphene is an amper, waxy solid with a molecular weight of 414 and melting point 70°-90°C. The physical and chemical properties are shown in Table 1.

TABLE 1

Physical and Chemical Properties of Toxaphene

Solubility	Vapor Pressure	Specific Gravity at 100°C/ 15.6°C.	Pounds per Gallon at 75°C.	Viscosity Centripose/ C °	Specific heat cal/g/°C
Highly Soluble in most organic solvents, but greater in aromatic solvents. Soluble in water ca 0.5 ppm	0.2-0.4mm at 25°C. 3-4 mm at 90°C.	1.63(avg)	13.8	89/110°C. 57/120°C. 39.1/130°C.	0.258/41°C. 0.260/95°C.

II. C.1. Manufacturing Process and Production of Toxaphene

The commercial production of toxaphene (U. S. Patents 2,565,471 and 2,657,164, Hercules) consist of reacting camphene with chlorine for 40 hours at 70°C and activated by ultraviolet irradiation and certain catalysts to yield the final product of chlorinated camphene

with a chlorine content 67-69 percent. The final product is a relatively stable material with a mild terpene odor and is a mixture of related compounds and isomers.

Toxaphene produced by Hercules is regularly bioassayed and subjected to chemical and physical tests batch by batch during manufacturing process.

Control of camphene feedstock quality and process variables is important in achieving a chemical substance of uniform properties. The specification item of infrared absorptivity at 7.2 μ (micron) used to distinguish toxaphene from other chlorinated terpene products such as strobane. A typical electron capture gas chromatograms are also prepared for each batch to check the uniformity of the materials.

Product specifications for toxaphene as shown below has been established by Hercules.

Product Specifications

Total organic chlorine, % by weight	67.0-69.0
Acidity, % by weight as Hcl	0.05% maximum
Drop softening point, 0°C	70 minimum
Infrared absorptivity at 7.2 μ	0.0177 minimum
Specific gravity at 100°C/15.6°C	1.600 minimum

II.C.2. Uniformity of Toxaphene Production

Bioassay is carried out regularly in each batch in order to obtain standards of identity appropriate for specifying, purchasing or evaluating toxaphene insecticides. The most convenient test organism is housefly, however, bioassay with other

insects such as plum curculio and southern armyworm is also recommended by Hercules Company.

Zweig (1971) reported that a series of nine samples from retained toxaphene production manufactured by Hercules in the interval 1949-1970 was bioassayed against female houseflies by the topical method. A laboratory toxaphene standard sample was used for comparative purpose.

Zweig (1971) also obtained infrared absorption spectra and electron capture gas chromatograms of the above series of nine samples of toxaphene. The results indicated that the toxaphene regularly produced by Hercules during the past 23 years is quite uniform in its properties.

II.D. Composition of Toxaphene

A large number of chlorinated terpene components are present in toxaphene and is due to the complexity of the chemical reactions in the synthesis of toxaphene. The chlorine content in the commercial product limited to 67-69% since insecticidal activity peaks sharply in that band. A typical gas chromatogram suggests that 30 or 40 principal constituents may exist. Separation of these components by a variety of means has been attempted. A description of the two most successful methods and their results are shown below.

II.D.1. Fractional Crystallization Method

Fractional crystallization applied to toxaphene utilized isoproponal solvent and carried through 5 levels, combining mother liquor and precipitated crops to obtain additional fractionation. Five crops (3 crystalline and 2 non-crystalline) were obtained.

Melting points varied widely, but insecticidal activity as measured by housefly bioassay was practically uniform. The results are summarized in Table II.

TABLE II.

Properties of Fractions From

Fractional Crystallization of Toxaphene

		%Kill (Flies--Bell Jar)			
		0.1% Conc.		0.05% Conc.	
Sample	Melting Range	AV.	S.D.**	AV.	S.D.**
Toxaphene	-	56(9)*	11.3	33(8)*	16.1
22	234-239°C	70(9)	5.4	39(8)	8.1
24	208-210°C	80(9)	8.8	40(8)	11.8
26	184-187°C	78(9)	9.3	40(8)	11.4
28	Noncrystalline semisolid	44(9)	8.1	29(8)	13.4
30	Viscous liquid	40(9)	8.3	22(8)	7.5

(*) Numbers in parentheses are numbers of determinations.

(**) S.D. = standard deviation of test results.

II.D.2. Craig Liquid-Liquid Separation Method

A 100-stage Craig liquid-liquid extractor was used with solvent pairs that included isooctane-acetonitrile, isooctane-methyl cellosolve and isooctane-dimethylformamide. The isolation of the individual

components was unattainable as indicated by lack of sharp peaks. The broad spread of the resolved sample and the uneven contour of the Craig's peaks profile do indicate some separation.

The system isooctane-acetonitrile concentrated ca 10% of the samples in the most polar phase and the chemical substance was relatively non-toxic to flies.

Fractions separated in the system isooctane-methyl cellosolve were tested individually. The results indicated the chemical components of lower toxicity to be present at both ends of the most polar and least polar spectrum. The toxicity of the middle fractions of this system are comparable to the middle fractions of the isooctane acetonitrile system. The biological data for the indicated fractions shown in Table III.

II.E. Analytical Methodology of Toxaphene

The analytical method for toxaphene analysis in formulation were described in two recently published books. (Dunn, 1964 and Row, 1970). These methods are based on analytical techniques such as: (1) Total chlorine method (metallic sodium reduction); (2) Total chlorine method (sodium biphenyl reduction); (3) Infrared spectrophotometry; and (4) Colorimetric (diphenylamine-zinc chloride).

In residue analyses for toxaphene, there were no analytical residue method based on gas chromatographic technique until 1963, (Coulson, 1959). This, any toxaphene residue data reported in literature, at least until 1963, were obtained by conventional spectrophotometric residue methods. Until about 1963, the two

TABLE III

Craig Countercurrent Fractionation of Toxaphene

Fraction No.	Sample	% of Original	% Fly Kill at Indicated Concentration, Topical Application 0.6 mg	0.5 mg	0.4 mg	Solvent System
X9675-23-A		11.4	3	0	0	Isooctane-Acetonitrile
-B		33.8	41	22	0	
-C		37.8	100	100	79	
-D		9.9	75	54	19	
-E		7.2	35	3	0	
Toxaphene Standard			91	81	28	
X9675-31-A	Tubes 5,10,15		7	0	0	Isooctane-Methyl Cellosolve
-B	Tube 45		31	22	16	
-C	Tube 85		100	97	57	
-D	Tube 125		79	63	28	
-E	Tube 185		0	3	0	
Toxaphene Standard			91	57	29	

methods of choice for residue analyses of toxaphene were: total chlorine determination and colimetric method. However, the total chlorine method is non-specific which measure total chloride of the sample and the colimetric method is of low sensitivity. Furthermore, both methods require rigorous "clean-up" procedure due to possible interferences from plant and animal extractives. Infrared spectroscopic method has never been used for residue determination due to lack of sensitivity.

Since about 1963, the gas chromatographic methods were employed to determine toxaphene residues in agricultural commodities (food, fiber, and feed), mammalian tissues and other natural specimens. The reported residue data must be very carefully scrutinized for the inherent difficulties for toxaphene analysis due to (1) the heterogenous composition of toxaphene and related chlorinated camphene products, (2) presence of other chlorinated hydrocarbon or pesticides such as PCB or DDT, etc., in various samples.

II.E.L. Clean-up Procedures

The two techniques, which are widely used to clean-up extracts of samples for toxaphene residue analysis are described by Reynold (1969). Absorption chromatography on selected florisil permits removal of plant pigments and some waxes; also separation of toxaphene from a few chlorinated pesticides. The separation of the most thiophosphate materials is accomplished by elution of toxaphene with 6% (U/V) diethyl ether in hexane. The treatment of sample extracts with concentrated sulfuric-fuming sulfuric acid (1:1) mixture

separates the fats and oil from toxaphene. In this technique, a 1:1 mixture of the sulfuric acids is ground with celite 545 and packed into a chromatographic column. A hexane solution of the extract containing fatty substances poured on the top of the column. The sulfonated fats and oils are retained on the column, while the toxaphene is eluted with hexane or 6% (U/V) diethyl ether in hexane.

Kawano et al , (1969) stated that the treatment with concentrated sulfuric-fuming nitric acid mixtures did not alter the analytical characteristic of toxaphene. Erro et al, (1967), reported that the nitration of the sample extract removed DDT as an interferring material in toxaphene residue analysis.

The two published methods for eliminating polychlorinated biphenyl (PCB) interferences from chlorinated hydrocarbon pesticides residues were evaluated for toxaphene residue analyses.

Reynolds (1969), published a method in which, PCB's along with heptachlor, aldrin and DDE are eluted from florisil column with 200 ml of hexane, but lindane, heptachlor epoxide, dieldrin, DDD and p,p DDT required 250 ml of 20% ethyl ether in hexane for complete elution.

Armour and Burke (1970), reported a method which involved elution of PCB's from Silicic acid/celite 545 column with 250 ml of hexane, while DDT and its analogs were eluted with 200 ml of a mixture of 1% acetonitrile + 19% hexane + 80% methylene chloride.

Both these methods found to be satisfactory to toxaphene residue analysis. In literature, the Reynold's method is preferred since it is a clean-up and separation on a single column. Armour and Burke's method is a two stage column chromatography since it requires prior clean-up on florisil column.

II.E.2. Chromatographic Methods

II.E.2.1. Paper Chromatography

Mills (1959), reported paper chromatographic methods for detection and semi-quantitative estimation of chlorinated pesticides including toxaphene. The limit of detection for toxaphene is about 0.2 micrograms. Sherman and Zweig (1971) stated that the chromatograms of clean-up extracts resulted in streaks instead of clearly defined spots.

II.E.2.2. Thin-layer Chromatography (T.L.C.)

Several thin-layer chromatography methods were published in literature for detection and quantitative estimation of toxaphene. The most preferred thin-layer chromatographic were those published by Schecter (1963) and Moats (1966). In these T.L.C. system, the aluminum oxide plates are spotted with clean-up extract and developed with hexane as mobile phase. After completion of solvent development, the plates are irridated with U.V. light to identify toxaphene. The limits of sensitivity is at the 0.5 microgram level. The methods, however, suffer from diffuse patterns and/or multispots.

II.E.2.3. Gas Chromatography

The first gas chromatographic method for chlordane, strobane and toxaphene was reported by Coluson (1962). Gaul (1966), published

gas chromatographic method for chlordane, toxaphene and strobane. In both of these methods, toxaphene resulted in multi-peaks, at least seven peaks. Witt et al, (1962) attempted to reduce these multi-peaks into a single peak using a 1-1/4 foot long column instead of the conventional 6-foot column length. They reported that, using microcoulometry detection system, a 0.5 microgram (μg) of toxaphene could be detected at a retention time less than 2 mins.

Terriere et al, (1966) reported a gas chromatographic method for determination of toxaphene level in water, aquatic plants and fish from lakes treated with toxaphene. They found that the apparent levels of toxaphene in untreated control samples ranged from an average of 0.38 ppb in water to 0.55 ppm in fish. They also noted that the absolute identification of single peak is impossible even after use of a short length column which decrease the resolution of toxaphene isomers.

Bevenue and Beckman (1966), published a "fingerprint" gas chromatography methods for positive identification of toxaphene. They used the three major characteristic peaks on 5% ZF-1/Chromosorb-W column, eluting after DDT, thus differentiating between DDT and toxaphene. The sensitivity of detection of toxaphene with EC detector is found to be 2 nonagram (ηg) under ideal conditions but more generally 5-7 nonagram is detectable. The authors, however, cautioned the reliability of these gas chromatographic residue data for the identification of toxaphene residue in agricultural commodities.

Further investigation into the '3 peak' phenomena at the later part of the gas chromatograms may possibly produce a definitive fingerprint of toxaphene. Gaul (1966), has recommended the use of the planimetry of the last four peaks as a quantitative measurement of toxaphene in the presence of DDT. If Kelthane is present in the sample, superimposing a toxaphene standard at about the same concentration as the unknown sample will correct the situation of interpretation of gas chromatograms. Erro (1967), reported that the last four peaks of toxaphene chromatogram are not always observed and sample containing toxaphene must be treated with concentrated sulfuric-fuming nitric acid mixture. Kawano et al, (1969), showed that the concentrated sulfuric acid-fuming nitric acid treatment does not appreciably alter toxaphene and isomeric chlorinated camphene, but such treatment effectively removes residues of other chlorinated pesticides such as: DDT, aldrin, telodrin, heptachlor, kelthane, perthane, tedion and trithion.

Archer and Crosby (1966) described an electron capture gas chromatographic method for quantitative determination micro quantities of toxaphene in milk, fat, blood and alfalfa hay after a pre-treatment of samples with KOH in ethanol for clean-up procedure and partial dehydrohologenation. The gas chromatographic column used were consist of 5% DC-710 silicone oil and 5% silicone oil and 5% SE-30 at 200°C. This method resulted in a single

modified toxaphene peak with retention time at 3.50 min. and was used for quantitative analysis and qualitative identification purposes. This peak has a shorter retention time than the modified peaks of DDT group (DDE and related compounds commonly encountered in samples).

The recommended gas chromatographic method, in literature, for the toxaphene residue analysis is as follows: A sulfuric acid-Celite 545 column clean-up followed by dehydrohalogenation and gas chromatography as modified by Archer and Crosby (1966). The sulfuric acid column separates fat and oil and the dehydrohalogenation yields a characteristic, reproducible pattern for dechlorinated toxaphene (Carlin, 1970).

The sample to be analyzed is dissolved in η hexane and put through a sulfuric-Celite column with 100 ml of redistilled η-hexane. After evaporation solvent hexane, the sample extract is treated with ethanolic 25% KOH at 75-80° for 15 mins. The reaction mixture is diluted with water and extracted with 0.5 ml η-hexane and an aliquats of the hexane layer are gas-chromatographed. The conditions for gas chromatography are as follows: Column - 9-foot x 1/8 inside diameter

Packing materials - 1:1 mixture 5% SE 30, 5% DC 710 silicone oil on (100/120) gas chrom Q

Column temp. - 200-210°C

Detector - electron capture detector

Column conditioning for 2 days at 250°C is highly desirable. The area of major peak of dehydrohalogenated toxaphene eluting at about 4.5 min. or the entire trace is measured by triangulation and use for quantitative estimation.

For some sample, if additional clean-up is required, this is done by florisil chromatography, toxaphene eluting with "6% ethyl ether in petroleum ether" fraction. A thirty nanograms of toxaphene produced 80% of full scale deflection with a 1 millivolt recorder (Archer and Crosby, 1966).

The recommended gas chromatographic conditions for unmodified toxaphene are as follows:

Column - glass column 5 foot x 1/8 i.d.

Packing Material - 3.8% UCW-98 on Diataport S (80/100 mesh).

Column temperature - 150°C

Carrier gas - Nitrogen 45 ml/min.

II.E.2.4. Residue Analysis by Gas Chromatography

Gas chromatographic analysis of toxaphene show that a definite identification by distinct peaks or fingerprints is unsatisfactory due to the heterogenicity of the compound. A distinct improvement of elution pattern was resulted from chemical modifications by acid treatment and/or dehydrohalogenation. Crop samples with a known spray history can be analyzed by gas chromatography or other analytical methods such as total chlorine, spectrophotometry.

Environmental samples of soils, water, air, wildlife, and fish and human specimens, which have been analyzed chlorinated pesticides by G.L.C. without prior chemical treatment cannot be unequivocally equated for toxaphene residue. There are several examples in literature for this fact. Burke and Giuffrida (1964), reported the retention times relative to Aldrin, of the major peaks of toxaphene on 10% DC200 at 200°C and a carrier gas flow of 120 ml/min. to be: 2.34; 3.06; 3.61; 4.51 (Aldrin = 1.00). Under the same conditions, DDD has a relative retention time 2.33 and p,p'DDT 3.03.

Gaul (1966), illustrated that methoxychlor has the same retention time as one of the major peaks of toxaphene possible the 4.51 min. peak reported above.

Therefore, an attempt must be made to evaluate reports of the presence or absence of toxaphene residues in natural specimens of unknown spray history in order to make a judgement of the validity of the reported findings. Although, the gas chromatographic methods used had apparent success to analyze for toxaphene with high degree of certainty. Most of the published residue data analyzed by G.L.C. did not use chemical pre-treatment method except in case of residue data cited by Archer and Crosby, (1966). Furthermore, most of the toxaphene residue data reports rely on the multi-peak phenomenon of toxaphene and few authors in published literature state their inability to identify and quantify toxaphene due to complexity of the G.L.C. elution pattern.

II.E.3. Spectroscopic Methods

Spectrophotometric methods may be used to assay toxaphene formulation. These methods are moderately sensitive for qualitative and quantitative analysis of residue of toxaphene. The greatest shortcoming of these methods is the need for exhaustive column clean-up since certain micro-quantities of plant waxes develop colors and interfere with the detection of toxaphene. These methods are useful as confirmatory test.

II.E.3.1. Colormetric

Hornstein (1957), published a colormetric method using thiourea and KOH to give yellow color and was used satisfactorily for estimation of toxaphene. Graupner and Dunn (1966), described a colormetric method which involves the development of a greenish-blue color by reaction of toxaphene with diphenylamine in the presence of zinc chloride. This method has been applied to both formulation and residue analysis. Nikolov and Donev (1963), developed a colormetric method using alkali and pyridine to form reddish brown color with toxaphene. This method appears to be unsatisfactory because of poor precision and accuracy.

Lisk (1960), described a colormetric method which involves combustion of the sample in a Schöniger flask and spectrophotometric determination of chloride based on the displacement of thiocyanate from mercuric thiocyanate in the presence of ferric ion.

Klien and Lisk (1967), compared the residue data of toxaphene on kale obtained by the diphenyl amine colormetric method with gas chromatography data. Agreement was good at residue levels ca ppm. The treatment of sample extracts with concentrated sulfuric-fuming nitric acid mixture resulted significantly reduced blank color formation.

II.E.3.2. Infrared Spectroscopy

Clark (1962), described a infrared spectroscopic method for quantitative determination of toxaphene in formulation (dust, wettable powder or emulsifiable concentrate). This method also can be used to measure toxaphene and DDT simultaneously. Concentrations of each component are read from calibration curves prepared from ccl_4 - solutions of known toxaphene/DDT content, by reading maximum and minimum absorbancy bands at 7.8 μ and 6.0 μ (micron), respectively for toxaphene and 9.1 μ and 5.8 μ for DDT.

Czech (1964), developed a rapid infrared method for toxaphene in animal dip and sprays which was based on the principles of Clark (1962) method. In a series of publications, Czech (1965a, 1965b), presented a rapid versatile test for toxaphene and many chlorinated hydrocarbon pesticides. The USDA (1964), published a "Testing Procedure for Emulsifiable Concentrate of Toxaphene", which presented a compilation of infrared procedures.

II.E.3.3. Total Chlorine Methods (Amperometrictitration)

In these methods, an isopropyl alcohol solution of toxaphene sample is treated with metallic sodium or a benzene solution of

the sample is reduced with sodium biphenyl reagent. The liberated chloride is then titrated by a nitrobenzene modification of the Volhard procedure. An alternate organic chlorine method for toxaphene sulfur dust involves the liberation of chloride by the Parr peroxide bomb method and the determination of chloride by the above method.

II.E.3.4. Schöniger Combustion

Hudy and Dunn (1957), described a method for the determination of toxaphene residue in animal fat, butterfat. This method involves combustion of sample followed by amperometric titration of the liberated chloride with silver nitrate. Sensitivity of the method was 5 mg of toxaphene.

Zweig et al, (1963), described a "total organic chloride" method in which they combined the Schöniger combustion method, following sulfuric acid treatment and amperometric titration of the liberated Cl^- ions. The overall sensitivity of 0.02 ppm toxaphene in whole milk was obtained. This method is recommended for samples of a known history.

II.E.3.5. Active Metal-Reaction Methods

In residue analyses of chlorinated hydrocarbon including toxaphene, the sodium reduction techniques are widely used.

Phillips and DeBenedictis (1959), described a modified sodium-isopropanol reduction method for the determination of toxaphene or other chlorinated hydrocarbon pesticides. Ligget,

(1964), Chapman and Sherwood (1957), used sodium biphenyl to determine organic chlorine. Menville et al, (1959), and Koblitsky et al, (1962), employed sodium dispersion technique for the decomposition of organic chlorine and was found to be specifically applicable for the estimation of chlorinated pesticides in animal fat.

Beckman et al, (1958), described a decomposition method for the determination of total organic chlorine, which consist of sodium-liquid ammonia decomposition of the sample, followed by an amperometric titration using coulometrically generated silver ions.

Cotlove et al, (1958), described an instrument named the automatic chloride titrator and commercially available at present. This instrument has a silver coulometer to generate the reagent and an amperometric end-point detecting system that automatically stop the titration after the end-point is reached. The time needed to complete the titration is recorded on a built-in electric timer. The time is easily related to the chloride content of the sample. In literature, this instrument is preferred for the quantitative measurement of chloride resulting from the above mentioned analytical techniques.

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Chapter III

Environmental Effects of Toxaphene and Strobane

The high toxicity to fish and other aquatic organisms including some species of waterfowl, persistence in water, and the accumulation of toxaphene residues in plants and aquatic animals prompted a ban on its use on Federal lands and federal aid projects by the U.S. Department of Interior.

III.A. Toxicity to Aquatic Organisms:

Aquatic organisms are highly sensitive to toxaphene, but extensive accidental fish kills have not been reported from its use.

III.A.1. Toxicity to fish:

High toxicity to fish was summarized by Pimental (1971). TLM and LC_{50} values for some species are presented in Table III.A.1. An early study by Ginsburg (1947) on goldfish (Carassius auratus) showed that 50 percent mortality occurred at 0.033 ppm and 100 percent at 0.063 ppm. Mayhew (1955) showed an LC_{100} of various concentrations to rainbow trout as follows: 1.0 ppm 4 hrs.; 0.5 ppm 12 hrs.; 0.25 ppm 12 hrs.; 0.1 ppm 16 hrs.; and 0.05 ppm also 16 hrs.

TABLE III.A.1

Toxicity Values for Various Fish to Toxaphene

Fish Species	Exposure Time (hr)	LC_{50} (ppm)	Source
Rainbow trout	24	0.05	Mayhew, 1955
Rainbow trout	48	0.0028	FWPCA, 1968
Largemouth bas	96	0.002	Macek and McAllister, 1970
Brown trout	96	0.003	Macek and McAllister, 1970
Bluegill	96	0.0035	Henderson, Pickering and Tarzwell, 1959
Carp	96	0.004	Macek and McAllister, 1970
Black Bullhead	96	0.005	Macek and McAllister, 1970
Goldfish	96	0.0056	Henderson, Pickering and Tarzwell, 1959
Coho salmon	96	0.008	Macek and McAllister, 1970
Rainbow trout	96	0.011	Macek and McAllister, 1970
Yellow perch	96	0.012	Macek and McAllister, 1970
Channel catfish	96	0.013	Macek and McAllister, 1970
Redear Sunfish	96	0.013	Macek and McAllister, 1970
Goldfish	96	0.014	Macek and McAllister, 1970
Fathead minnow	96	0.014	Macek and McAllister, 1970
Bluegill	96	0.018	Macek and McAllister, 1970

Table III.A.1 (cont'd.)

Fish Species	Exposure Time (hr)	LC_{50} (ppm)	Source
Fathead minnow			
hard water	96	0.0051	Henderson, Pickering and Tarzwell, 1956
soft water	96	0.0075	Henderson, Pickering and Tarzwell, 1956
Guppies	96	0.02	Henderson, Pickering and Tarzwell, 1959
Chinook salmon	96	2.5 ppb	Katz, 1961 (TLM)
Coho salmon	96	9.4 ppb	Katz, 1961 (TLM)
Rainbow trout	96	8.4 ppb	Katz, 1961 (TLM)
Rainbow trout	96(53°F.)	0.0084 (TLM)	Mahdi, 1966
Stone rollers	96(53°F.)	0.014 (TLM)	Mahdi, 1966
	96(73°F.)	< 0.005 (TLM)	Mahdi, 1966
Goldfish	96(53°F.)	0.094 (TLM)	Mahdi, 1966
	96(73°F.)	0.05 (TLM)	Mahdi, 1966
Golden shiner	96(73°F.)	0.006 (TLM)	Mahdi, 1966
Bluntnose minnow	96(53°F.)	0.03 (TLM)	Mahdi, 1966
	96(73°F.)	0.0063 (TLM)	Mahdi, 1966
Black bullhead	96(53°F.)	0.025 (TLM)	Mahdi, 1966
	96(73°F.)	0.0018 (TLM)	Mahdi, 1966

Bandt (1957) reported that toxaphene used to control field mice in Germany was washed into a stream and caused fish mortality. Experiments showed that amounts of 0.125 mg/ai/l

was toxic to rainbow trout and carp.

Henderson, et al., (1959) found that among ten chlorinated hydrocarbon compounds, all except BHC were extremely toxic to fish with 96 hr. TLM values generally below 0.1 ppm. Changes in water quality characteristics (pH, alkalinity, hardness) had no apparent effect on toxicity. The amount of toxaphene that may be applied to the water surface to produce a 96 hr. TLM was 3.5 ppb or 0.03 lb. per surface acre of water 3 feet deep.

Katz (1961) in addition to data in the above table also reported the TLM of toxaphene to threespine stickleback (Gasterosteus aculeatus at 5 and 25 parts per thousand salinity and obtained 96 hr. exposure figures of 8.6 and 7.8 ppb, respectively.

Workman and Neuhold (1963) described lethal concentrations of toxaphene for goldfish, mosquitofish (Gambusia affinis), and rainbow trout (Salmo gairdneri) as fiducial limits of a 24 hr. LC_{50} in ppm (goldfish) as: .005 .066 for "sinking" and .005 - .040 for "floating" type toxaphene. The "floating" type was formulated to mix simultaneously with water and does not settle to the bottom whereas the regular insecticidal type does. Rainbow trout showed .015 .054 for sinking and .047 .049 ppm

for floating types. For mosquitofish the extremes were .005 - .049 for sinking as opposed to .008 - .059 ppm for floating formulations. These extremes were based upon water of differing qualities from three sites in Utah.

Butler (1963) showed 24 and 48 hour TLM values for white mullet (Mugil curema) of 0.0055 ppm for both exposures. In 1964, Butler reported the concentration of strobane and toxaphene in sea water causing 50 percent mortality, 24 and 48 hr. EC_{50} to juvenile fish as: 0.055 and 0.0085 mg/l strobane for sheepshead minnow (Cyprinodon variegatus), and 0.0022 and 0.001 for toxaphene on spot, Leiostomus xanthurus.

Ferguson, et al., (1965) reported upon the tolerances of black bullheads (Ictalurus melas) and mosquitofish from a transect of the lower Mississippi River. Approximate 36 hr. TLM values in ppb from four main river sites for mosquitofish showed 20 ppb while a resistant population gave 480 ppb. Mississippi River data on black bullheads from three sites gave 36 hr. TLM readings of 12.5, 50, and 22.5 ppb. A susceptible population elsewhere showed 3.75 ppb.

Use of toxaphene used on 16 North Dakota lakes caused residues from 0.005 to 0.035 ppm. At levels below 0.025 ppm incomplete mortality of fishes occurred. Concentrations of

0.025 0.035 ppm induced complete mortality. Five of seven lakes where kills were complete were successfully restocked within seven months after treatment (Henegar, 1966).

Lethal concentrations of toxaphene were determined for the stoneroller, golden shiner, goldfish, black bullhead, and bluntnose minnow in water at 53°F., 63°F., and 73°F.; rainbow trout were tested at 53°F. Toxicity of toxaphene increased as the temperature increased. The 96-hour TLM values were below 0.1 ppm of toxaphene in all species tested. Goldfish were the most tolerant of the species tested and sensitivity other species could not be ranked due to similarity of results obtained (Mahdi, 1966).

Chronic exposure of spot, Leiostomus xanthurus, to sublethal concentrations of toxaphene in sea water was conducted by Lowe (1964). Earlier tests had shown that exposure to 0.5 ppb caused mortality in 5 days, but concentrations of 0.1 and 0.01 ppb were less than the lethal level throughout a 5-month exposure period. Fish surviving chronic exposure were subjected for 48 hours to concentrations of 0.5, 1.0, 2.0 and 3.0 ppb to determine if resistance had been acquired. Mortality in groups at 3.0 and 2.0 ppb was 100 percent and no mortality at 0.5 ppb.

Hussein, et al., (1967) reported that lowering the temperature

of water reduced the toxicity of toxaphene for Gambusia sp. and Tilapia zilli. Toxaphene concentrations ranging from 1.0 to 0.072 ppm at 32°C. caused 100 percent mortality at exposures of 8 hours or less. Similar tests at 16°C. showed 100 percent mortality in both species after exposure to 1.0 or 0.165 ppm within 29.5 hours. At this lower temperature, 0.072 ppm cased 67 percent mortality to Gambusia after 68.5 hours and 73 percent mortality to Tilapia after 28 hours.

Macek, et al., (1969) studied the effects of temperature on the susceptability of blue gills to toxaphene. Data are presented in Table III.A.2.

TABLE III.A.2

TL_{50} values (micrograms active ingredient/liter for bluegills tested against toxaphene

Exposure time	Temperature - C°. 12.7	18.3	23.8	R.I.S.*
24 hours	9.7	6.8	6.6	1.46
96 hours	3.2	2.6	2.4	1.71

R.I.S. = relative increase in susceptibility

Histopathological effects were found in the head region of striped mullet (Mugil cephalus) embryos exposed to toxaphene for 96 hrs. at concentrations up to 0.5 ppm. Glandular structures in the optic region were larger and more numerous when exposed to the higher concentrations. These structures appeared to be

mucous glands and their anomalous condition may have been due to epithelial irritation. Histopathological effects were also noted in larvae of largemouth bass, (Micropterus salmoides). Necrosis was found in kidney tissues and the lining of the digestive tract of larvae exposed for 14 days to 10 percent of the 96 hrs. TL_{50} administered in the food. There was near total destruction of the kidney tubules (Courtenay and Roberts, 1973).

In the comet strain of goldfish exposure to 1.8 µg/1 toxaphene at 25°C. for 96 hours produced severe changes in behavioral patterns. At 264 hrs. exposure under the same conditions, the 1.8 µg/1 group again showed stronger signs of behavioral pathology, although they were able successfully to perform tasks of some complexity. Moderate behavioral pathology was detected in the 0.44 µg/1 group with fewer parameters showing abberations. The 0.44 µg/1 group showed increasing evidence of toxication by toxaphene. Thus at 96 hours behavioral pathology was detectable at a concentration of toxaphene 1/25 of that necessary to produce a TLM. One of the major pharmacological effects was a heightening of responsiveness to external stimuli (Warner, et. al., 1966).

III.A.1a. Toxaphene as a piscicide:

Lennon, et al., (1971) reviewed the history of the use of toxaphene that 0.04 mg/1 (ppm) killed all fish in a small

pond. Tarzwell (1950) suggested that the compound may be useful in fish management. First major field trails as a fish toxicant were conducted by Hemphill (1954) in two Arizona lakes in 1951. A concentration of 0.1 mg/l (ppm) eliminated the rough fish, including carp in one lake and greatly reduced their numbers in another. The killing action of toxaphene was slow in comparison with rotenone and extended over a period of days. Insect life in the lakes was severely affected, but not eliminated.

Tanner and Hayes (1955), evaluating toxaphene use in Colorado, indicated that a lake may be treated effectively with the compound for about $0.10/1,000 m3 as compared with $0.77/1,000 m3 with rotenone. Admitting that toxaphene is attractive from the standpoint of economy, they advised that it is an extremely powerful poison of greater toxicity to warmblooded animals than rotenone. Toxaphene may persist for at least 7 months at toxic level in a lake at pH 8.0 or higher.

In Michigan, Hooper and Grzenda (1957) demonstrated that toxaphene is more toxic to fish in hard water than in soft water, and more toxic in warm water than in cold water. Although toxaphene at 0.1 mg/l gave good results against fish, the lakes remained toxic for periods of 2 to 10 months. Bottom invertebrates

were killed in large numbers, but quickly reappeared in abundance.

The observation that 5 µg/l (ppb) of toxaphene in hard water killed small fish, but left large bluegill and largemouth bass unharmed, prompted Fukano and Hooper (1958) to suggest that the compound had potential as selective poison. Stringer and McMynn (1958) applied the compound at 0.01 to 0.10 mg/l in eight alkaline lakes in British Columbia, and eliminated all fish and amphipods. The lakes were still toxic to fish 9 months after treatment. In a followup study, Stringer and McMynn (1960) discussed methods for dispensing toxaphene, the killing time for fish, the lower lethal concentrations for a number of fish species, and factors influencing degradation. They pointed out that small concentrations of toxaphene applied to control cyprinids and cottids in deep, clear, stratified lakes in British Columbia may persist at toxic level for 2 years. On the other hand, detoxification proceeds so rapidly in some turbid lakes that relatively high concentrations produced only partial fish kills.

Tests of toxaphene against fish in the laboratory and field were conducted in Iowa by Rose (1958). Over 25 µg/l was necessary to kill carp and bullheads in cold clear water whereas 200 µg/l were needed with the same species in highly turbid water. Silt was suspected of having a direct detoxifying effect.

Results of 4 years of reclamation efforts with toxaphene in Nebraska lakes were reviewed by McCarraher and Dean (1959). They found that at least 0.5 mg/l of toxaphene was required for complete kills of fish in Sand Hill likes having moderate alkalinity, high turbidity, and pH 8.5 to 9.5 They recorded serious problems, however, during aerial applications. An aerial application of 0.61 mg/l of toxaphene in one lake killed every wild duck, but carp and bullheads survived. A similar application of 0.52 mg/l in another lake killed all fish, but also killed 33 percent of the mallards and 29 percent of the gadwalls, but less than 10 percent of the gulls and grebes present in the treated area. Each of the aerial applications of toxaphene was accompanied by losses of waterfowl ranging from 15 to 100 percent. Dead mammals possibly associated with the operations included raccoon, dog, skunk, and cow. In contrast, there were few mortalities of birds when toxaphene was sprayed in the water from a boat.

Gebhards (1960) documented the increasing use of toxaphene in States and provinces of western North America. He also discussed the toxicity of toxaphene to humans, livestock, waterfowl, fish, and aquatic invertebrates, and stated that the factors increasing the rate of detoxification of toxaphene are sunlight, high concentration of dissolved oxygen, high temperature, water circulation, and turbulence. Kallman, Cope, and

Navarre (1962) demonstrated that aquatic vegetation in a treated lake accumulated high concentrations of toxaphene and that rainbow trout and black bullhead concentrated the toxicant within their bodies. Hunt and Keith (1963) discussed the biological magnification of toxaphene residues that resulted in death of birds. Following treatment of Big Bear Lake in California, Johnson (1966) recommended that toxaphene not be used as a fish poison anywhere in the State. Terriere, et al., (1966) observed the persistence of toxaphene in Oregon lakes up to 6 years, with residues accumulating up to 14 ppm in rainbow trout and 17 ppm in aquatic plants. Similar studies were performed with toxaphene by Nehring (1964), Johnson, Lee, and Spyridakis (1966), Henegar (1966), and Moyle (1968).

A survey in 1966 indicated that toxaphene ranked second to rotenone as a fish toxicant in the United States, but ranked first in Canada (Stroud and Martin, 1968). The limited use of the toxicant against fish in Germany was described by Anwant (1968). Applications of the compound as a fish toxicant declined rapidly in the United States in the late 1960's however, due in part to a ban imposed by the U.S. Department of the Interior in 1963 (Dykstra and Lennon, 1966). This ban was prompted by the persistence of toxaphene in water, its high toxicity to invertebrates and vertebrates, especially waterfowl, and accumulation of residues in plants and animals. Further

use of toxaphene as a fish toxicant in Federal projects or federally aided projects was forbidden. Walker (1969) observed that toxaphene has been one of the most extensively misused fish toxicants in the United States and Canada.

Big Kitoi Creek, on Afognak Island, Alaska, was treated with toxaphene in July 1961 to remove sculpins predaceous on pink salmon fry. Dispersion and penetration of toxaphene into the streambed were determined, as well as time required for detoxification. The population of sculpins in the creek before treatment was estimated at 30,000, of which 82 percent were in the size range considered predaceous on pink salmon fry. Extent of predation was determined by examination of stomachs of 180 sculpins. Considering the rate of predation, it was estimated that, of 847,500 $\pm$ 418,600 fry in the gravel 3 months before treatment, 12 percent may have been eaten by sculpins before the fry migrated to salt water. Toxaphene was applied for 18.5 hours at an average concentration of 1.5 ppm. Assuming that, if the creek had not been treated, 30,000 sculpins would have been present in the spring of 1962, then the treatment possibly saved approximately 135,000 pink salmon fry in 1962 (Meehan and Sheridan, 1966).

An experiment was conducted to determine whether toxaphene can be used to eradicate lake-dwelling sea lampreys and to determine its effect on fish populations. In East Bay, a 78acre

lake on the Sucker River, Alger County, Mich., an estimated concentration of 100 parts per billion was maintained for 14 days. The sea lamprey larvae were more resistant to toxaphene than were the fish, but a complete kill was indicated. One year after treatment, sea lampreys were absent from the lake, while the fish population had recovered (Gaylord and Smith, 1966).

III.A.1.b. Effects on crustaceans:

Since many pesticides were developed to control terrestrial arthropods, marine crustaceans might well be expected to be sensitive to the same chemicals. Butler (1963) reported the results of bioassays on brown shrimp (Penaeus aztecus) and blue crabs (Callinectes sapidus). Concentrations of toxaphene in sea water causing mortality or loss of equilibrium in 50 percent or more of the test animals were: brown shrimp - 24 hours, EC_{50} - 0.0066 ppm; 48 hours, EC_{50} - 0.0049 ppm; and blue crab - 24 hours, EC_{50} - 0.33 ppm.

Laboratory tests were conducted to determine 96 hour TL_{50} values for toxaphene under different conditions of salinity, temperature and dissolved oxygen on developmental stages of blue crab, pink shrimp (Penaeus duorarum), drift line crab (Sesarma cinereum), and mud crab (Rhithoropanopeus harrissii).

The 96 hour TL_{50} for various stages of drift line crab larvae were 0.054 ppb for stage I zoea, increased about 10 fold to 0.76 ppb for stage II zoea and 0.74 ppb for stage III zoea; increased about 10 fold again to 6.8 ppb for stage IV zoea and 8.4 ppb for the megalopa. The 96 hour toxaphene TL_{50} for pink shrimp decreased from 2.2 ppb for nauplii, to 1.8 for protozoea to 1.4 ppb for mysis. The 96 hour toxaphene TL_{50} for stage I of the mud crab was 43.75 ppb.

George, et al., (1957) reported upon the effects of aerial applications of strobane of 0.3 lb./acre on wildlife in tidal marshes of Delaware. No marked differences were observed in mortality between treated vs. control areas for fish (16 and 14 percent dead) or to blue crabs (Callinectes sapidus). However, marsh fiddler crabs (Uca pugnax) decreased 68 percent on the treated areas compared with 16 percent on the control. This was one of the dominant crustaceans in the area and provides food for birds and mammals.

The insecticide tolerances of two crayfish populations (Procambarus acutus) in South Central Texas were studied by Albaugh (1972). LC_{50} values at 48 hours for crayfish from an uncontaminated area and adjacent to a treated cotton field were 60.7 and 90.2 ppb, respectively. In contaminated habitats in the Mississippi River delta, fresh water shrimp (Palaemonetes kadiakensis) were 6-25 times more resistant to seven insecticides

(including toxaphene) than shrimp from an uncontaminated area (Naqvi and Ferguson, 1970). In an earlier report by Ferguson, et al., (1965) this same species of fresh water shrimp from a bayou fed by runoff from treated cotton fields was exposed for 36 hours to several concentrations of toxaphene and found to have TLM values 3 times those of shrimp from an untreated area.

A fresh water shrimp Gammarus lacustris, common in prairie fresh water lakes and ponds and readily collected and cultured, was found to be a sensitive bioassay organism for the rapid detection of chlorinated hydrocarbon insecticides in aqueous suspension. This shrimp was most sensitive to lindane and endrin and levels as low as 0.01 ppm can be detected in 54 and 175 minutes, respectively. The LT_{50} values (lethal time for 50 percent knock-down) for toxaphene based upon duration of exposure was 460 minutes at 0.05 ppm; 360 at 0.1; 96 at 0.5; and 72 at 1.0 ppm (McDonald, 1962).

III.A.1.c. Effects on Mollusks:

Oysters and other shellfish are highly susceptible to effects of pollution. They have limited mobility with feeding and respiration requiring exposure of gill cilia and oral cavity to large amounts of circulating water. These activities must be stopped by closing the shell if bivalves are to avoid pollution. Pesticide effects can be measured by inhibition of shell growth (Mason and Rowe, 1969).

Butler (1963) found that the concentration of toxaphene in sea water causing a 50 percent decrease in shell growth for 96 hour exposure was 0.057 ppm.

Oysters (Crassostrea virginica), were reared from juveniles to sexual maturity in flowing sea water chronically polluted with low levels (3.0 ppb) of DDT, toxaphene and parathion and mixtures of the 3 chemicals. Oysters grown in the mixture (1 ppb each of the three chemicals) were about 10 percent less in body weight than the controls after 9 months. Weights and heights of separate groups (1 ppb each of DDT, toxaphene or parathion) were not statistically different from the controls. In oysters reared in the pesticide mixture, tissue changes were observed in kidney, visceral ganglion, gills, digestive tubules, and tissues beneath the gut. Oysters accumulated relatively high levels of toxaphene (30 ppm by the 24th week) but dropped to 3.0 ppm 4 weeks after the end of pesticide exposure (Lowe, et al., 1971). The amount of residual toxaphene found in oyster tissues after 10 days exposure to 0.05 ppm toxaphene was 146 ppm, or a biological concentration of 2920 x (Wilson, 1966).

Chlorinated pesticides levels in the eastern oyster were studied from selected estuarine areas of the South Atlantic and Gulf of Mexico (Bugg, et al., 1967). In general these were either not detected or were found at relatively low levels. Toxaphene was found in only 6 of 133 samples with a median of 0.08 (range $<$0.01 - 1.0 ppm).

The possible reintroduction of toxaphene into estuarine biota from dredging and displacement of contaminated sediment in Terry

Creek, Brunswick, Ga., was studied. In the estuary, the sediments near a toxaphene plant outfall were found to be contaminated with toxaphene approaching 2,000 ppm and oysters collected 2 miles from the outfall were found to contain residue levels near 6 ppm. Analyses of oysters and sediment before and after dredging operations revealed no significant increase of toxaphene residues resulting from the dredging and resultant spoil runoff (Durant and Reimold, 1972).

After 4 weeks exposure of 0.1 ppm of toxaphene, 50 percent of the oyster population died. Only 1 ppb inhibited the development of clam eggs by 50 percent and also reduced the growth of mature oysters after 7 days of exposure by 64 percent (USDI, 1960). Molluscs in lakes, however, were apparently unaffected by a dosage of 0.1 ppm toxaphene (Hooper and Grzenda, 1957).

The snail population in a marsh treated with toxaphene at 2 lb/A (105 ppm in water) was zero in about 10 days (Hanson, 1952). The snails did not start to reinvade the treated areas until a month had passed.

Mortality of Belzoni (resistant) and State College (susceptible), Mississippi clams (Eupera singleyi) was checked by exposure to various concentrations for 72 hours (Naqvi and Ferguson, 1968). Six of 20 susceptible specimens succumbed to 300 ppb toxaphene and all were killed by 700 ppb. Among resistant individuals only 3 were killed at 300 ppb and maximum loss of 12 was reached at 600 ppb. The same trend was evident among snails (Physa gyrina) where at 350 ppb 16 susceptible but only 4 resistant snails died. The LD_{100} values for the two groups were 450 and 550 ppb.

III.A.1.d. Effects on amphibians:

Frog and toad control was discussed by Mulla (1962). He showed the toxicity of toxaphene to tadpoles of the anurans Rana catesbeiana, Bufo borealis, and Scaphiopus hammondi to be such that complete kill occurred at application rates of 0.1 to 0.5 lb/ac. On a golf course, 95 to 98 percent of juvenile toads were controlled with a combination of toxaphene and DDT at 2 and 1 lbs/ac. In 1963 Mulla reported further on effects of 0.5 lb/ac. toxaphene and reported 100 percent kill of both mosquito fish and tadpoles of the bullfrog, Rana catesbeiana, after 24 hours exposure. Exposure to 0.1 lb/ac. toxaphene has no effect on tadpoles after 6 days.

Bioassays with the northern cricket frog, (Acris crepitans), southern cricket frog (A. gryllus) and for Fowler's toads (Bufo woodhousei fowleri) were made with specimens collected near cotton fields and from pesticide-free areas (Ferguson and Gilbert, 1967). Population tolerance appeared to reflect environmental contamination and probable history of exposure. With A. crepitans from an area bordered on one side by a cotton field 36 hour TLM_{50} values were 0.5 mg/ml and 5.4 mg/ml from a site surrounded by cotton fields. Extremes for B. w. fowleri were 0.6 mg/ml (bordered on one side by cotton) to 50.0 mg/ml (surrounded by cotton).

Sanders (1970) determined that the 24-hour LC_{50} for Fowler's toad tadpoles and chorus frog (Pseudacris triseriata) tadpoles exposed to toxaphene was 0.60 ppm and 1.7 ppm, respectively. For the toad the 48-hr. LC_{50} was 0.29 and the 96-hr. LC_{50} was 0.14 mg/l.

Extended exposure effects on the chorus frog showed 0.7 for 48 hours and 0.5 mg/1 for 96 hours.

III.A.1.e. Effects on Other Organisms:

Laboratory bioassays were conducted with toxaphene to determine its toxicity and immobilization values for two species of daphnids, Daphnia pulex and Simocephalus serrulatus. Estimated 48-hour EC_{50} immobilization values, in micrograms per liter, for S. serrulatus were 19 at 60°F. and 10 at 70°F. For D. pulex it was 15 at 60°F. It ranked fourth most toxic among 12 chlorinated hydrocarbon pesticides (Sanders and Cope, 1966).

The growth of pure cultures of marine phytoplankton in the presence of 17 toxicants was reported by Ukeles (1962). Toxaphene, a mixture of chlorinated camphenes, was the most toxic of the chlorinated hydrocarbons tested. A concentration of 0.01 ppm was tolerated by four species but 0.15 ppm was lethal to all organisms. Monochrysis lutheri showed a striking sensitivity to this compound and as little as 0.001 ppm was lethal.

The effects of toxaphene upon phytoplankton of a Colorado reservoir were investigated by Hoffman and Olive (1967). The selected area was treated with enough of a water emulsifiable preparation of 60 percent toxaphene to cause a residual of 0.1 ppm. Following the application of toxaphene, protozoans decreased from high counts taken in October to zero in December. No protozoans were collected from the water surface until May. Fish toxicants reduced the

size of the rotifer populations. Populations of Entomostraca in treated lakes decreased to zero. Experiments by Hemphill (1954) and Moretti (1948) indicated that Entomostraca are also killed by toxaphene.

An earlier study by Cushing and Olive (1956) dealt with effects of toxaphene upon the macroscopic bottom fauna of the same lake. Toxaphene applied at 0.1 ppm had a marked effect upon the Tendipedidae (Chironomidae) population. Living larvae were absent from samples taken 3 days posttreatment, and recovery was not complete until 9 months later. Chaoborus larvae exhibited no immediate effects, but were absent 6 months after poisoning and did not reappear before the study ended. Oligochaetes showed no adverse effects from toxaphene but rather increased during the study period.

The effect of toxaphene on the benthos of a thermally-stratified lake in Wisconsin was observed by Hilsenhoff (1965). Chaoborus larvae were the only profundal benthic organisms that were adversely affected by treatment of a dimictic lake with toxaphene to eradicate undesirable fish. The larvae were eliminated, and had not become reestablished 2 years after treatment. Subsequent to the removal of the fish, a large population of Chironomus larvae appeared, and when the lake was restocked with 7 species of fish, the larval population dropped to its former level. More than a year after treatment, a sustantial population of Procladium larvae appeared, probably resulting from the removal of carp and consequent reduction in turbidity, increased growth of rooted aquatic vegetation and restoration of higher dissolved oxygen levels. The temporary

absence of fish also favored an increase in the physid snail population.

Grzenda, et al., (1964) studied effects of chemical pollution on zooplankton, bottom fauna, and fish populations in a northern Alabama drainage system. Toxaphene and BHC were present in all water samples collected in 1959 and 1960 in amounts considered to be sublethal to aquatic animals in a single dose. Mean seasonal recoveries for toxaphene ranged from 29 to 140 ppt. Individual samples varied from 10 to 217 ppt. There was no convincing evidence that continuous toxaphene contamination resulted in gross damage to any of the animals studied. Scarcity or fluctuations may have resulted from other unfavorable conditions such as changes in discharge and high turbidity.

Pesticide effect on growth and assimilation (^{14}C) in a fresh water alga was evaluated by Stadnyk, et al., (1971). Low density populations of green alga, Scenedesmus quadricaudata, were studied in terms of growth and metabolism rather than death. Concentrations of 0.1 and 1.0 mg/1 toxaphene were used. Toxaphene decreased cell number at both levels of treatment, but cell biomass was reduced only 3 and 4 percent. In two day cultures at the higher concentration there was a 450 percent increase in carbon fixation.

The susceptibility of millipedes to insecticides was studied by Fiedler (1965). Three millipede species, Spinotarsus fiedleri, Poratophilus pretorianus, and P. robustus, causing damage to potatoes and other plants in South Africa, were checked for pesticide effects. Percent mortality in 7 days after being dipped for 30 seconds in 0.2 percent EC toxaphene was 60 percent for Spinotarsus

and 0 for Poratophilus spp. When exposed in bait form, toxaphene mortality to Spinotarsus was 30 percent in 7 days but again had no effect on the other genus.

Development of resistance by the tobacco bud worm, Heliothris virescens in Texas to toxaphene + DDT and Strobane + DDT occurred during the period 1963-65. During this period the LD_{50} for toxaphene + DDT increased from 0.57 to 3.52 mg/g of larvae and for Strobane from 0.51 to 11.12 mg/g. These values indicated an increase in resistance of the tobacco bud worm of approximately 6-fold to toxaphene + DDT and 22-fold to Strobane + DDT (Adkisson, 1967).

Laboratory studies were reported in which planktonic animals and algae, periphyton, and insect nymphs were exposed to toxaphene in both single applications of 0.03 ppm and chronic applications of 0.01 and 0.02 ppm. The results showed that single sub-lethal doses of toxaphene are insufficient to produce accumulations in fish-food organisms which would cause fish mortalities, but with chronic doses, the amounts accumulated by Daphnia and periphyton can be toxic to fish. This explains the long residual period of toxicity which has been observed when toxaphene is used as a fish poison (Schoettger and Oliver, 1961).

Toxaphene was used in an experimental program to control rough fish at Big Bear Lake, San Bernardino County California. It was applied at 0.2 ppm and was concentrated by plankton and other members of the food chain. A sample of a planctor Cladocera,

collected four months after the application, contained 73 ppm toxaphene. Fatty tissues of goldfish had over 200 ppm and fat from a pelican which died at the lake contained 1,700 ppm of toxaphene. There was a substantial die-off of birds at Big Bear Lake which was attributed to toxaphene. Cladocera collected at the lake proved to be toxic when test fed to hatchery trout. Ten months after the insecticide application, trout were able to survive in the lake, and it was restocked with catchable trout. Fillets from trout taken two months later were analyzed and found to contain 3 ppm of toxaphene. This accumulation occurred after the lake was considered biologically safe for fish (Hunt and Keith, 1962).

Two mountain lakes which were treated with toxaphene to eradicate the fish were subsequently investigated to determine the movement and fate of toxaphene in the lakes (Terriere, et al., 1966). The concentration in the shallow eutrophic lake, initially treated to contain about 88 ppb of toxaphene in 1961, decreased to 0.63 ppb in 1962, to 0.41 ppb in 1963, and to 0.02 ppb in 1964. The concentration in the deep oligotrophic lake, initially treated with about 40 ppb in 1961, declined to 2.10 ppb in 1962, to 1.20 ppb in 1963, and to 0.64 ppb in 1964. Both plants and animals absorbed toxaphene and apparently played an important role in eliminating it from the lakes. Plants in the deep lake with water containing about 2-ppb levels of toxaphene concentrated it to

levels as high as 17 ppm, while invertebrates concentrated toxaphene to maximum levels of 5 ppm (Terriere, et al., 1966). In the shallow lake the concentration factor was about 500 times for aquatic plants, 1,500 times for aquatic invertebrates, and 15,000 times for rainbow trout. In the deeper lake, trout could not be restocked in the lake for 6 years, although the concentration 3 years after treatment had decreased to 0.84 ppb.

In a similar investigation by Kallman, Cope and Navarre (1962), a shallow lake was treated to contain 0.05 ppm of toxaphene. Within 1 month the concentration of toxaphene declined to 0.001 ppm but remained at about this level for an additional 250 days. Mortalities in lower aquatic animals of 100 percent which were common after 24 hours of exposure to 0.01 ppm supported findings in the previous study (Terriere, et al., 1966). Aquatic vegetation concentrated toxaphene to high levels (400 times that found in the water).

Residues of pesticides in various components of the Flint Creek, Alabama aquatic biota were reported by Grzenda and Nicholson (1965). It appeared that although toxaphene occurred more or less as a chronic contaminant in water, its occurrence in bottom fauna was sporadic. Mean residues of 550 ppb were found in Hexagenia and 430 ppb in a mixture of Ephemeroptera, Trichoptera, Hemiptera and Odonata. In an earlier paper on the same area, Grzenda, et al., (1964) concluded that there was no convincing evidence that toxaphene contamination resulted in gross damage to zooplankton

or botton fauna. Sensitivity of the methods used was insufficient to measure changes in productivity.

In 48-hr. exposures to various concentrations of nine insecticides, six species of cyclopoid copepods from a pesticide contaminated ditch near Belzoni, Mississippi, displayed higher tolerances than did the same species for areas of minimal pesticide contamination near State College, Mississippi. Similarly, a clam, Eupera singleyi, and a snail, Physa gyrina, from the Belzoni locality had higher tolerances to toxaphene than the same species from near State College. Extremely high concentrations of 6,000 ppb toxaphene failed to kill the worm, Tubifex, from Belzoni in 72-hr. tests.

The potential effect of increased tolerances in these invertebrate species is to increase the amount of pesticide residues available to higher trophic levels (Naqvi and Ferguson, 1968).

Big Kitoi Creek, on Afognak Island, Alaska, was treated with toxaphene in July 1961 to remove sculpins predaceous on pink salmon fry. Bottom fauna decreased in numbers and weight after the toxaphene treatment: insects were completely eradicated; some other invertebrate groups were not completely eliminated. Posttreatment recruitment of bottom fauna began later in the summer; a year later the pretreatment levels of biomass had not yet been reached. Species composition of bottom fauna a year after treatment differed somewhat from that before treatment (Meehan and Sheridan, 1966).

A chronic toxaphene exposure study with brook trout was discussed in a progress report by Schoettger (1973). Brook trout fry exposed to toxaphene concentrated the insecticide over 76,000 times, but adult brook trout concentrated toxaphene by only 16,000 times. Brook trout adults and fry were exposed to five concentrations of toxaphene in flow-through diluters for 15 days (fry) and for 161 days (adults). Mean water concentration of toxicant necessary to produce these concentration factors was 0.502 mg/1.

The LC_{50} of toxaphene tested against various species of arthropods is found in table III.A.3.

The 48-hour EC_{50} (immobilization value at 60°F.) for waterfleas, Simocephalus serrulatus and Daphnia pulex, to toxaphene was 19 ppb and 15 ppb, respectively (Sanders and Cope, 1966).

Certain aquatic Oligochaetes in lakes were apparently unaffacted by a toxaphene treatment of 0.1 ppm (Hooper and Grzenda, 1957).

Brown shrimp tolerated toxaphene at a dosage of 40 to 50 ppb, whereas white shrimp has a toleration limit of 75 to 90 ppb (USDI, 1960).

Toxaphene at 0.1 ppm appears to have an inhibitory effect on 3 groups of plankton (Entomostraca, Rotatoria, and Protozoa) which are important fish foods (Hoffman and Olive, 1961).

Toxaphene (10 to 60 mg/beetle) was found to prevent oviposition in coccinellid beetles (Coleomegilla maculata) (Atallah and Newsom, 1966).

The bottom fauna in a lake with a 10 ppb level of toxaphene declined in number of individuals, but returned to normal density within 14 days (Hooper, 1960).

TABLE III.A.3

The LC_{50} for various arthropods to toxaphene.*

Arthropod Species		Exposure Time (hr)	LC_{50} (ppm)	Source
Stonefly	(Claassenia sabulosa)	24	0.0006	Sanders & Cope, 1968
"	(Pteronarcella badia)	24	0.0092	"
"	(Pteronarcys californica)	24	0.018	"
Amphipod	(Gammarus lacustris)	24	0.180	Sanders, 1969
Stonefly	(P. californicus [sic])	48	0.007	Cope, 1966
"	(P. californica)	48	0.007	FWPCA, 1968
Waterflea	(Daphnia pulex)	48	0.015	Cope, 1966
"	(D. pulex)	48	0.015	FWPCA, 1968
"	(Simocephalus serrulatus	48	0.019	Cope, 1966
Mayfly	(Beatis sp.)	48	0.047	Cope, 1966
Amphipod	(G. lacustris)	48	0.070	FWPCA, 1968

* as listed by Pimentel (1971).

III.A.1.f. Resistance and Other Effects:

While acute and chronic toxicities of insecticides to fish have been recorded by many workers, Boyd (1964) was one of the first to point out other possible deleterious effects. He noted that pregnant female mosquitofish (Gambusia affinis) at almost any stage of pregnancy may abort when exposed to a pesticide solution, even though the female survives. About 5 percent of pregnant females exposed to toxaphene aborted. Aborting was noted only at concentrations above the threshold toxicity.

Approximate LD_{50} values were determined for four populations of mosquitofish (Boyd and Ferguson, 1964). The results showed resistance and cross resistance in populations having past exposure to toxaphene. The 36 hr. LD_{50} values for fish from the four sites were .01, .16, .06 and .48 ppm, the latter being the heavily treated area. Evidence favoring a genetic basis for resistance was presented wherein toxicity levels remained constant in progeny of resistant fish which were reared in the absence of pesticides.

The spectrum of cross resistance in mosquitofish was broadened to cover strobane by Boyd and Ferguson in another paper in 1964. Nonresistant fish showed about 70 percent loss after 48 hr. exposure to 0.1 ppm and 100 percent kill after 9 hrs. at 0.25 ppm. On the other hand, the resistant population showed no losses until the 5.0 ppm level was reached, and never exceeded about 60 percent loss at intervening levels as high as 30 ppm. Strobane resistance, a material not used in the area before 1963, was considered most likely a consequence of past selection by toxaphene, a closely related material. The level of strobane resistance (over 300 fold) actually exceeded that earlier reported for toxaphene (40 fold) by the same authors.

Ferguson, et al., (1964) studied the resistance to toxaphene in three species of fresh water fish - golden shiners (Notemigonus crysoleucas), bluegills (Lepomis macrochirus), and green sunfish (Lepomis cyanellus); the results of these studies are summarized in Table III.A.4.

TABLE III.A.4

Comparative Toxicity of toxaphene to resistant (Twin Bayou) and non-resistant (State College) strains of fish

	36-hour Median Tolerated Limit (ppb)	
	State College	Twin Bayou
Golden shiners	30	1200
Bluegills	23	1600
Green Sunfish	38	1500

Carnivores at the top of the chain such as large-mouthed bass or crappie were not collected at Twin Bayou. This may be the result of biological magnification of insecticides having a more severe effect on animals at the top of a food chain.

The effects of combinations of insecticides on susceptible and resistant mosquito fish were studied by Ferguson and Bingham (1966). All possible paired combinations of endrin, DDT, toxaphene and methyl parathion were used. Whereas the combination of two insecticides produced higher mortality among resistant fish than did the individual insecticides, the combination scarcely exceeded the individual kills of toxaphene in tests of susceptible fish. Results did not indicate additive effects wherein the combination mortality exceeded the sum of mortalities produced by individual insecticides.

Patterns of toxaphene resistance in the mosquito fish were studied by Culley and Ferguson (1969). Extent of insecticide resistance

in a resistant population (Belzoni, Mississippi) was compared with that of a susceptible population (State College, Mississippi) using 28 insecticides of 5 major groups. Results of 48-hour bioassays showed that the resistant strain had developed high resistance only to the toxaphene-endrin related insecticides. Strobane showed LC_{50} values of 11 and 6,253 ppb for susceptible and resistant strains, a 568-fold difference. Comparable figures for toxaphene were 12 and 4,519 ppb, respectively, or a 376-fold difference.

The toxicities of toxaphene and three other insecticides to resistant and susceptible mosquito fish in static and flowing solution were observed by Burke and Ferguson (1969). In static tests where mortality occurred, increased concentration produced a corresponding increase in mortality. The same was true in flowing solutions, and this was true of both resistant and susceptible fishes. Time-mortality curve tests showed that toxaphene produced greater mortality in flowing solutions than in static ones. Normally, pesticide concentrations in natural waters decline, as do concentrations in static tests. This study showed dynamic tests to be more stringent that static tests, perhaps unrealistically so.

Resistant green sunfish and golden shiners from near Belzoni, Mississippi and susceptible individuals of the same species from near Starkville, Mississippi were compared in 48-hour static bioassays against six common insecticides (Minchew and Ferguson, 1970). Green sunfish from the Belzoni population were resistant to chlordane,

heptachlor, lindane and strobane, but not to parathion. Golden shiners from the Belzoni test group were resistant to lindane and strobane, tolerant to chlordane and heptachlor, and susceptible to parathion.

Studies showed that populations of insecticide resistant fish from near heavily treated cotton fields at Belzoni, Mississippi were subjected to relatively brief and irregular periods of selection after rains (Finley, et al., 1970). Runoff from cotton fields increased mortality among caged susceptible and resistant fish. Residue analyses revealed that DDT and toxaphene were the two insecticides of selective importance. DDT and toxaphene residues increased in whole fish and water samples after runoff. In highly contaminated environments, resistance appears to be essential for survival of fish populations.

Succinic dehydrogenase activity in mitochondria of insecticide resistant and susceptible mosquitofish was assayed (Moffett and Yarbrough, 1972). Intact and disrupted mitochondria from livers and brains were used. Toxaphene inhibited intact mitochondria preparations from resistant brain tissue. Succinic dehydrogenase activity in intact susceptible mitochondria was inhibited by toxaphene. In mitochondria with disrupted membranes, enzymatic activity was inhibited by insecticides in both resistant and susceptible fish. Inhibition of succinic dehydrogenase by insecticides only after disruption of the resistant mitochondrial membrane indicates that a membrane barrier exists in insecticide-resistant fish.

Insecticide resistance in mosquitofish from Texas was noted by Dziuk and Plapp (1973). The Navasota susceptible population gave 48-hour LC values as 31 ppb for LC_{50} and 63 ppb for LC_{90}. The Bee Creek population showed an LC_{50} value of 212 ppb and 425 ppb for LC_{90}. The Old River population showed a 48-hour LC_{50} of 301 and an LC_{90} of 612 ppb. The latter figure represented a 9.7X increase in resistance. These figures suggest that a widespread gradual decrease in susceptibility occurs within the species. Results suggest that resistant populations of mosquitofish are more common than previously suspected, especially with the discovery of resistance as a result of urban contamination in the Bee Creek population where resistance was 6.8X as compared to the Navasota susceptible strain.

III.A.1.g. Residues in Fish:

Fish were collected from 50 sampling stations located in the Great Lakes and in major river basins throughout the United States as part of a national pesticide monitoring program. Of the 590 composite samples which were examined, all but 6 contained DDT or DDT metabolites (Henderson, et al., 1969). In laboratory cross check samples, only 1 of 5 laboratories reported toxaphene at levels of .36 ppm in chain pickerel from Old Town, Maine; 1.06 ppm from white sucker in the Delaware River; 1.25 from white perch

in Lake Ontario; and .01 and .24 ppm from Lake Erie fresh water drum (fall 1967 data only). Scattered positive samples which were detected in the remainder of the study appear in Table III.A.5.

TABLE III.A.5

Toxaphene residue in fish, 1967-1968

Species	Location	Residues in ppm
Spotted sucker	Cooper River, S. C.	.03
Carp	Miss. R., Luling, La.	.03
Smallmouth buffalo	Arkansas R., Pine Bluff	.01 and .02
Largemouth bass	Keystone Reservoir, Okla.	.01
Carp	Colorado River, Ariz.	.01
Channel catfish	Utah Lake, Provo, Utah	.01

The monitoring program continued in 1969 with 147 composite samples collected at 50 stations. No residues of toxaphene were reported in any of the 1969 samples (Henderson, et al., 1971).

Chlorinated hydrocarbon residues were reported for representative fishes of the lower Colorado River basin. While most residues were in the ppb range, toxaphene was a common contaminant at levels as great as 172.9 ppm (Johnson and Lew, 1970). Fat from carp collected at Buckeye Canal contained 50.0 ppm and gills of 2 specimens from Picacho Reservoir had residues of 0.45 and 0.42 ppm. Muscle of channel catfish contained 6.8 ppm and fat, 11.38 ppm. Threadfin shad gave whole body residues of 1.05 and gills, 4.75 ppm. The Sonoran sucker (Catostomus insignis) had skin and muscle residues up to 5.78 ppm and viscera residues in 8 samples ranging from 2.75

to 172.92 ppm. Samples of Gila sucker (Pantosteus clarki) contained 25.0 for whole fish and up to 42.94 ppm for viscera. Collection sites for the latter two species were Mesa and Tempe Canals.

The ecological distribution of pesticides in the Lake Poinsett, South Dakota ecosystem was reported by Hannon, et al., (1970). Toxaphene was present in four species of fish at tissue and fat levels of 83 and 2705 ppb for white sucker, 176 and 1152 ppb for carp, and 74 and 1382 ppb for northern pike.

The distribution and magnitude of toxaphene residues among fish in a northern Alabama watershed which was devoted largely to cotton production are presented in Table III.A.6. (Grzenda and Nicholson, 1965).

TABLE III.A.6

Toxaphene residues in fish collected from the Flint Creek, Alabama Basin

Species	Number of Fish in composite	Concentration (ppm) portion Edible	Non-edible
Green sunfish	9	0.10	0
Green sunfish	7	0.58	1.09
Largemouth bass	1	1.60	9.15
Largemouth bass	1	0.51	0.45
Largemouth bass	1	0.30	0.30
Redhorse suckers	3	0.95	2.93
Redhorse suckers	9	1.03	1.26
Creek chubs	3	0.90	2.50
Creek chubs	3	1.02	3.30
Grizzard shad	1	1.32	1.70
Warmouth bass	1	0.30	0.71

Hughes and Lee (1973) studied accumulation of toxaphene in fish in Wisconsin lakes which had been treated for rough fish control with 0.1 mg/l toxaphene. Bluegills stocked 10 to 16 months after treatment accumulated residues of nearly 10 µg/g and reproduced successfully. Residue accumulation was more closely related to fat content of fish than fish weight. Edible flesh of bluegills contained less than 10 percent of the whole body burden of toxaphene residues, and up to 27 percent of the residues in this tissue was removed by pan frying.

Ettinger and Mount (1967) discuss the need for information on the interaction of drinking water, stream water quality, and food standards to assure that a wildcaught fish would be safe to eat. Although a fish may be killed in water containing minute quantities of such lethal agents as toxaphene, it may contain higher amounts of pesticides before death removes it from the major food chain of man. The authors thus apply the minimum response level of animal toxicity prepared by W.J. Hayes (Advisory Committee on use of the Public Health Service Drinking Water Standards - 1965). Hayes' values for lowest dietary level of toxaphene with minimum effects on rats was 25 ppm from which the authors extrapolated a maximum reasonable stream allowance of 2.5 ppb. Captured fish from water containing this amount should not be toxic to man, and their environment should be suitable for maintaining a harvestable crop - which means fish survival, reproduction and normal growth. Additional data are given in Table III.A.7.

TABLE III.A.7

TOXAPHENE RESIDUES IN FISH AND REPTILES

Species	Tissues Analysed	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Bass, Largemouth *Micropterus salmoides*	Flesh Viscera	13 samples 8 samples	0.0-0.3 Av. 0.05 0.2-2.0 Av. 1.13	Keith & Hunt 1966 " " "
Bluegill *Lepomus macrochirus*	Whole body?	22 samples	0.0-2.06 Av. 0.48	Epps, *et al.*, 1967
Bullhead, Black *Ictalurus melas*	Whole body	89 samples	0.37-15.2	Kallman, *et al.*, 1962
Bullhead, Brown *Ictalurus nebulosus*	Flesh	3 analyses	0.0-0.19 Av. 0.06	Keith & Hunt 1966
Carp *Cyprinus carpio*	Flesh Viscera	1 analysis 2 analyses	0.1 0.0-0.1 Av. 0.05	Keith & Hunt 1966 " " "
Catfish, Channel *Ictalurus punctatus*	Whole body? Fat	27 samples 8 analyses	0.0-6.6 Av. 2.23 0.4	Epps, *et al.*, 1967 Keith & Hunt 1966
Crappie, Black *Pomoxis nigromaculatus*	Whole body	3 analyses	0.0-0.1 Av. 0.03	Keith & Hunt 1966
Chub, Tui *Siphateles bicolor*	Whole body	29 analyses	0.0-8.0 Av. 1.09	Keith & Hunt 1966
Fish Sp. not given	Whole body	Not given	TR.-8.0	Keith, 1966
Pumpkinseed *Lepomis gibbosus*	Whole Body	1 analysis	0.04	Keith & Hunt 1966
Salmon, Atlantic (1962) *Salmo salar* (1963) (1964)	Tissue extract Tissue extract Tissue extract	2 analyses 2 analyses 2 analyses	2.6-2.9 Av. 2.75 1.11-5.5 Av. 3.24 1.5-2.1 Av. 1.8	Terriere, *et al.*,1966 " " " " " "
Shad, Gizzard *Dorosoma cepedianum*	Whole body?	17 samples	0.0-4.75 Av. 1.49	Epps, *et al.*, 1967

Table III.A.7 (cont'd)

Species	Tissues Analysed	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Spot	Juvenile (No mortality but thickened gill lamellae at 0.1 and 0.01 ppb)			Butler, 1964b
Leiostomus xanthurus	Juvenile (50% mortality within 6 days at 0.5 ppb)			Butler, 1964b
Trout, Brown Salmo trutta	Tissue extract	5 + analyses	8.3-24.8 Av. 12.46	Terriere, et al.,1966
Trout, Rainbow	Whole body	37 sampled	0.43-5.4	Kallman, et al., 1962
Salmo gairdneri (1962)	Tissue extract	6 or more analyses	1.2-12.0 Av. 5.7	Terriere, et al.,1966
(1963)	Tissue extract	6 or more analyses	2.75-13.7 Av. 7.72	" " "
(1964)	Tissue extract	6 or more analyses	3.2-3.8 Av. 3.5	" " "
	Whole body	5/5	0.13,0.28,0.43, 0.98,1.3	Erickson, 1968
	Flesh	19 analyses	0.0-2.57 Av. 0.22	Keith & Hunt 1966
Turtle, Softshell Trionyx spinifer	Viscera	1 analysis	1.0	Keith & Hunt 1966

III.B. Effects of Toxaphene and Strobane on Wildlife

The available data which describe the effect of toxaphene on mammals were summarized by Pimentel (1971) in the following manner. The LD_{50} for mule deer, 139 to 240 mg/kg. Tucker and Crabtree (1970) reported that for mule deer the LD_{50} of toxaphene administered orally in capsules was 139-240 mg/kg. Under similar method of administration the LD_{50} for young mallards was 70.7 mg/kg; for young pheasants, 40.0 mg/kg; for young bobwhite quail, 85.4 mg/kg; for sharptailed grouse, 10 to 20 mg/kg; for fulvous tree ducks, 99.0 mg/kg; and for lesser sandhill cranes, 100 to 316 mg/kg. The LC_{50} for pheasants was 542 ppm, 828 for bobwhite quail, 538

for mallards, and for coturnix 686 ppm of toxaphene in diets of 2-week-old birds when fed treated feed for 5 days followed by clean feed for 3 days (Heath, et al., 1972).

Dahlen and Haugen (1954) reported median lethal dosages of toxaphene for bobwhite quail were 80-100 mg/kg. The acute oral LD_{50} for mourning dove was listed as 200-250 mg/kg. Keith (1964) checked the acute oral toxicity of toxaphene to young white pelicans and found that one bird died at 100 mg/kg, another showed no toxication at 200 mg/kg while a third specimen showed intoxication but survived at 400 mg/kg. Heath and Stickel (1965) determined the acute LC_{50} values of feeding diets containing toxaphene for 5 days followed by 5 days on clean feed. Following this protocol they derived LC_{50} for bobwhite quail chicks of 834 ppm, and 564 for mallard ducklings.

Flickinger and Keith (1965) conducted a 3-month study of chronic exposure of young white pelicans to toxaphene. At 10 ppm in the diet the only attributable effect was a reduction of ecto - and endo - parasites. However, 50 ppm produced tremors, convulsions and death in 4-6 weeks. Effects on parasites were inversely related to the amount of pesticide in the diet.

The comparative toxicity of several pesticides to bobwhite quail was determined by feeding tests. Toxaphene, incorporated in the diet at 0.1 percent caused 100 percent kill in 13 days, while 0.05 percent produced 75 percent mortality in 25 days (Linduska and Springer, 1951).

DeWitt (1956) reported upon effects of strobane to bobwhite quail and pheasants. Symptoms of acute toxicity and heavy mortality resulted when young quail chicks were fed diets containing 300 ppm strobane, but normal survival occurred at 50 ppm. With lower levels growth rates were supressed. Feeding 500 ppm throughout the winter to adult birds had no apparent effects upon survival or weight gains. Approximately 50 percent of the experimental birds survived after receiving 50 ppm strobane in the growth, winter maintenance and reproduction diets. For quail fed 50 ppm strobane during winter and spring, neither egg production nor fertility were affected. However, hatchability was reduced 15 percent and chick survival was only 60 percent that of the controls.

According to Genelly and Rudd, (1956a) thirty-three pheasants, including 3 males, survived three months feeding trials with diets containing 300 ppm toxaphene. However, pheasants at this dosage lost weight. Egg production hatchability was reduced significantly in the group fed 300 ppm toxaphene. Mortality of young was significantly greater than that of controls for the first two weeks (Genelly and Rudd, 1956b).

Post (1949) reported the following LD_{50} values for toxaphene: chukar partridge - 50 mg/kg; pheasants - 200 mg/kg; and sage grouse 90 mg/kg. He commented further upon the effects of toxaphene and chlordane bran bait for grasshopper control. Range lands totaling

4,205,708 acres in Wyoming were treated in this manner in 1949 and 1950. On 1,200 acres of baited land effects of pesticides were found in 18 dead or ill birds. Another 122 birds were found dead or affected in baited plots, but cause of death could not be proved. One muskrat, three skunks and one field mouse were found dead in baited plots. When a marsh in North Dakota was treated with toxaphene at 2 lb/A (105 ppm in water), sora, coot, and black tern produced no young; however, the red-wing blackbird production was not affected (Hanson, 1952). Toxaphene and oil proved harmful to all animal life studied except adult birds and some small crustaceans. Only six birds were known to be reared from 21 nests or broods.

The effects of toxaphene poisoned grasshoppers upon pheasant chicks was investigated by Harris (1951). Three birds which were fed diets of poisoned grasshoppers at 35 days of age were all dead after 84 hours. They had consumed an average of 52.6 grams of grasshoppers. Another group of 5 birds, age 41 days, died within 72 hours of exposure (4 within 48 hours). Average intake was 24 grams per bird. Another group, which also had access to clean mash and water, ate 71.7 grams of grasshoppers each over a 10-day period but did not succumb. These results suggest that young pheasants can be killed by eating poisoned grasshoppers.

Wildlife effects from grasshopper insecticides sprayed on shortgrass range were studied by McEwen, et al., (1972). Toxaphene

was sprayed at the rate of 1 lb. insecticide in 3/4 pint of fuel oil per acre on about 177,000 acres of blue grama grassland in New Mexico for control of the range caterpillar. In the first week post-treatment, no change was observed in bird numbers on the census lines, and no mortality. During the second week post-spray, birds decreased significantly in comparison with untreated grama rangeland in the same area. Three horned larks, two meadowlarks, one killdeer, one cowbird, and one mourning dove were found dead on the sprayed area. Analysis of the carcasses indicated toxaphene residues ranging from less then 0.1 to 9.6 ppm. Toxaphene was not detected in four horned larks collected live before spraying, but ranged from 0.4 to 1.0 ppm in four horned larks and one meadowlark collected live 2 to 3 weeks postspray.

The effects of toxaphene on wildlife when used as an aerial spray for grasshopper control were reported by Finley (1960). Rangeland on the Crow Indian Reservation, Montana was treated with 1.5 lb./acre. Nearly all casualties resulting from toxaphene were associated with a stock pond. Total wildlife casualties included 20 birds, 17 reptiles and 53 amphibians. Bird species containing toxaphene residues included meadowlark, Wilson phalarope, killdeer, house wren, and Brewer's blackbird.

Four samples of range caterpillars contained from 7.2 to 34.0 ppm toxaphene, and four postspray samples of blue grama had from 6.7 to 51.6 ppm. Of three deer mice and one grasshopper mouse

collected on the edge of the sprayed area, only one specimen contained detectable toxaphene. Seven months after the toxaphene application, two grass samples and four horned larks were collected for analysis. The grass samples (mostly blue grama) contained 5.5 and 8.3 ppm toxaphene, while the horned larks had from 0.2 to 0.8 ppm. Conclusions from this study were that toxaphene at 1 lb/acre had a severe impact on the grassland fauna and ecosystem (McEwen, et al., 1972).

Tucker (1971) reported that the percentage of egg shell thinning in coturnix quail 7 days after an oral dosage of 10 mg/kg was only 0.5 percent different from the control. However, this species is considered refractory to the egg shell thinning phenomenon.

III.B.1 Use of Toxaphene for Vole Control:

Serious vole infestation in German forests, and the failure of traditional methods of control, led to extensive trials of several chemical methods in 1954 and 1955. The results are reported by Schindler (1955) and (1956), who indicated that the compounds toxaphene and Endrin, which are widely known as insecticides, were highly effective for control of voles at application rates about five times those normally recommended for insecticide purposes. It appears that because of their almost continuous feeding habit and consumption of large quantities of treated vegetation, the animals are killed by oral poisoning within a few hours after treatment. These rates are equivalent to 1.78 to 2.68 lb. active

toxaphene per acre. No injurious effects were observed among game, birds, and livestock which inhabited the several thousand hecares which were treated. It was suggested that the susceptibility of voles to the toxins, compared with other vertebrates is associated with their exceptionally large feeding capacity in relation to their body weight.

Preliminary experiments on the use of toxaphene for the control of shorttailed voles in young forest areas in Great Britain were made by Holmes, et al., (1958). The short-tailed vole, Microtus agrestis L., is essentially a grassland animal, with a marked perference for the dense low cover of rank grasses and herbaceous species commonly present in young forest plantations, derelict agricultural areas, and waste land. Forest planting operations invariably favor an increase in vole populations, owing to the unchecked growth of grass and general herbage following exclusion of grazing animals from the planted area. Under these conditions the vole population may rise to a high level, causing considerable damage to the planted crop.

Results of first trials in 1956 at two forest sites indicated reductions in vole numbers on treated areas, but plot sizes were inadequate to give conclusive results. The main trial in 1957 was carried out on two-acre unit plots, and results show generally high levels of control with toxaphene at 2.25 lb. per acre. Toxicity hazards to domestic animals, and wild birds and animals other than voles, are not fully known, and practical applications are

not recommended until these hazards can be assessed in more extensive trials.

Control of meadow mice in orchards was reported by Eadie (1959). Toxaphene has been used to some extent to control meadow mice in California and Washington, as well as in Europe, where it has been used successfully to control some types of field mice in young forest plantations. Trials with toxaphene ground sprays were conducted from 1952 to 1958 in New York. The material used was toxaphene emulsifiable concentrate (6 pounds of actual toxaphene per gallon) applied at the rate of 5 pounds of actual toxaphene per acre. Good reductions in population (84-100 percent) were obtained in light to medium mowed cover, but the percentage of kill dropped sharply in heavy or matted, unmowed cover. One plot with heavy to medium cover and old mowings showed an 84 percent kill, but plots with heavy, matted, and unmowed cover throughout showed kills of only 40 and 60 percent.

III.B.2. Residues in Wildlife:

Data pertaining to residues in fish and wildlife are presented in Tables III.B.2. Robinson (1950) found residues in dead birds collected from two areas adjacent to Nebraska lakes treated for fish control. In one group, taken from a lake treated at 0.05 ppm, residues in birds were blue-winged teal - 4.7 and 9 ppm; sandpiper - 10 ppm; and shoveller - 12 ppm. At a second lake treated at 0.4

ppm, night heron contained 64 ppm, coot 17 ppm, and mallard 10 ppm.

Finley (1960) studied effects of a 1.5 lb./ac. toxaphene application for grasshopper control on the Crow Indian Reservation, Montana. Toxaphene was found in all except one bird analysed. Results were: meadowlark 12-67 ppm; meadowlark nestling 8 ppm; Wilson's phalarope 70-265 ppm; killdeer 6.440 ppm; adult house wrens - 165 ppm; and one Brewer's blackbird -19 ppm.

Some reptile and amphibian data were: painted turtle (3 young) - 154 ppm; tiger salamander larvae 15-100 ppm, and leopard frog 68-520 ppm. Residues in pond water 4 hrs. after first spraying was $<.02$ ppm and 6 hrs. after second spraying about .03 ppm.

TABLE III.B.2

TOXAPHENE RESIDUES IN WILD BIRD TISSUES

Species	Tissues Analysed*	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Blackbird, Brewer's *Euphagus cyanocephalus*	WB found dead	1/1	5.0	Keith, J.O., 1966
Coot, American *Fulica americana*	WB found dead	1/1	17.0	Keith, J.O., 1966
Cormorant, Double-Crested *Phalacrocorax auritus*	WB	2/2	2.2-9.5 Av. 5.8	Keith & Hunt, 1966
	Carcass found dead	1/1	9.5	Keith, J. O., 1966
Cowbird, Brown-Headed *Molothrus ater*	WB found dead	1/1	0.98	Hillen, 1967
Dove, Mourning *Zenaidura macroura*	WB found dead	1/1	Tr.	Hillen, 1967

*WB-whole body; L-liver; K-kidney; H-heart; BM-breast muscle

TABLE III.B.2 (cont'd.)

Species	Tissues Analysed*	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Duck, Mallard *Anas platyrhynchos*	WB found dead	1/1	10.0	Keith, J.O., 1966
Duck, Shoveler *Spatula clypeata*	WB found dead	1/1	12.0	Keith, J.O., 1966
Egret, common *Casmerodius albus*	WB	1/1	17.0	DeWitt, *et al.*, 1962
	Carcass	3 samples analysed	Av. 9.2	Keith, J. O., 1966
	WB	4 samples	0.0-17.0 Av. 6.92	Keith, J.O., 1966
Grebe, Eared *Podiceps caspicus*	WB	5 samples analysed	0.0-4.0 Av. 1.9	Keith, J.O., 1966
Grebe, Western	Fat	5 samples analysed	0.0-39.0 Av. 12.66	Keith & Hunt, 1966
Aechmophorus occidentalis	WB	8 samples analysed	0.0-0.8 Av. 0.02	Keith & Hunt, 1966
1960	Carcass	6 samples analysed	Av. 0.3	Keith, J.O., 1966
1960	Fat	2 samples analysed	Av. 31.5	Keith, J.O., 1966
Gull, Ring-Billed *Larus delawarensis*	Fat	1 sample analysed	4.8	Keith & Hunt, 1966
Heron, Black-Crowned Night *Nycticorax nycticorax*	WB?	No. not given	Up to 5.0	Keith, *et al.*, 1966
	WB	3 samples analysed	0.0-15.0 Av. 5.0	Keith & Hunt, 1966
1960	Carcass	1 sample analysed	15.0	Keith, J.O., 1966
	WB found dead	1/1	64.0	Keith, J.O., 1966

*WB-whole body; L-liver; K-kidney; H-heart; BM-breast muscle

TABLE III.B.2 (cont'd.)

Species	Tissues Analysed*	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Heron, Great Blue	WB	1/1	10.0	DeWitt, et al., 1966
Ardea herodias	WB	1/1	10.0	Keith & Hunt, 1966
	Carcass	1/1	10.0	Keith, J.O., 1966
Killdeer	WB	2/2	6.0	Keith, J.O., 1966
Charadrius vociferus	WB found dead	1/1	9.6	Hillen, 1967
Kingbird, Western	WB young	1/1	4.0	Keith, J.O., 1966
Tyrannus verticalis				
Lark, Horned	WB sacrificed	4/4	0.41-0.96 Av. 0.7	Hillen, 1967
Eremophila alpestris	WB found dead	3/3	Tr., 2.5,3.3	Hillen, 1967
Meadowlark, Western	WB found dead	3/3	Tr.,Tr., 0.6	Hillen, 1967
Sturnella neglecta	WB	2/2	13.0	Keith, J.O., 1966
	WB Young	3/3	3.0	Keith, J.O., 1966
Pelican, White	L) 1 bird	1/1	8.0	(DeWitt, et al., 1962
Pelecanus erythrorhynchos	k)		13.0	(DeWitt, et al., 1962
	L) 1 bird	1/1	9.0	(DeWitt, et al., 1962
	K)		14.0	(DeWitt, et al., 1962
	1/2 bird		4.0	(DeWitt, et al., 1962
	L 1 bird	1/1	7.0	(DeWitt, et al., 1962
	K		4.0	(DeWitt, et al., 1962
	H,L,K,BM	49 samples analysed	0.0-82.0 Av. 3.6	Keith & Hunt, 1966
	L	3 samples analysed	7.0-9.0 Av. 8.0	Keith & Hunt, 1966
	K	3 samples	4.0-14.0 Av. 10.33	Keith & Hunt, 1966
			Same data given in	Keith, J.O., 1966
1960	Carcass	1 sample	4.0	Keith, J.O., 1966
1960	L	3 samples	8.0	Keith, J.O., 1966
1960	K	3 samples	10.3	Keith, J.O., 1966
1961	H,L,K,BM	12 samples	7.6	Keith, J.O., 1966

*WB-whole body; L-liver; K-kidney; H-heart; BM-breast muscle

TABLE III.B.2 (cont'd.)

Species	Tissues Analysed*	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Phalarope, Wilson's *Steganopus tricolor*	WB found dead	4/4	41.0	Keith, J.O., 1966
Sandpiper Sp. not given	WB found dead	1/1	10.0	Keith, J.O., 1966
Shrike, Loggerhead *Lanius ludovicianus*	WB sacrificed	1/1	Tr.	Hillen, 1967
Teal, Blue-Winged *Anus discors*	WB	3/3	7.0	Keith, J.O., 1966
Wren, House *Troglodytes aedon*	WB	2/2	41.0	Keith, J.O., 1966

*WB-whole body; L-liver; K-kidney; H-heart; BM-breast muscle

TABLE III.B.2

TOXAPHENE RESIDUES IN BIRD TISSUES AND EGGS

Species	Tissues Analysed	No. of Specimens	Range or Average of Residues Found in ppm	Literature Citation
Tissues				
Pelican, White *Pelecanus erythrorhynchos*	H,L,K,M	Not given	82.0	BSFW Publ. 43, 1967
Lark,Horned *Eremophila alpestris*	WB?	4 shot	0.7	BSFW Publ. 43, 1967
	WB?	7 found	Tr. - 9.6	BSFW Publ. 43, 1967
Shrike, Loggerhead *Lanius ludovicianus*	WB?	1 shot	0.7	BSFW Publ. 43, 1967
Blackbird, Red-Winged *Agelaius phoeniceous*	Fat, B,K,L,H, Gizzard, M)	Not given	Tr. in all tissues	El Sayed, *et al.*, 1967
Eggs				
Cormorant, Double-Crested *Phalacrocorax auritus*	Yolk	2 samples	10.0	Keith & Hunt, 1966
Duck, Gadwall *Anas strepera*	Yolk	5 samples analysed	Av. 0.04	Keith & Hunt, 1966
Gull, Ring-Billed *Larus delawarensis*	Yolk	1 sample	0.2	Keith & Hunt, 1966
Pelican, White *Pelecanus erythrorhynchos*	Egg	22 analysed	0.0-6.7 Av. 0.39 Same data given in	Keith & Hunt, 1966 Keith, 1966a
Tern, Forster's *Sterna forsteri*	Yolk	1 sample	15.5	Keith & Hunt, 1966

III.C. Effects on Domestic Animals:

Formulations of toxaphene such as dusts, dips and backscrubbers are registered for the control of ectoparasites on livestock. Several studies have been performed to determine the effects of toxaphene used for these purposes. Seventeen heifers and young cows weighing from 500 to 800 lbs. were fed varying amounts of bran grasshopper baits containing toxaphene. Sublethal doses were between 35 - 110 mg/kg. The lowest lethal dose was 144 mg/kg (Marsh, et al., 1951).

Marsh (1949) fed hay treated with toxaphene to 14 yearling steers. Two steers receiving hay treated at 8 lb./ac. developed temporary nervous symptoms but recovery was rapid. Feeding period was 4+ months and average daily toxaphene intake was 7.9 mg/kg. Fourteen lambs fed similar doses of toxaphene treated hay (1, 2, 4 and 8 lb./ac.) showed no toxic symptoms. Welch (1948) reported that one steer given 50 mg/kg toxaphene exhibited no toxic effects.

Radeleff (1949) reported on experimental oral drenching of goats and sheep. Doses of 50, 100, 170 and 250 mg/kg of toxaphene were toxic in 13 trials. One hundred mg/kg was fatal to one of two sheep, 170 mg/kg killed one goat of four animals, (2 sheep, 2 goats) and 250 mg/kg killed 3 of 5 animals (1 sheep, 2 goats).

Adipose tissues from animals fed 4 months on alfalfa hay which had been sprayed with toxaphene at 1 and 2 lb./ac. showed toxaphene concentrations of about 25 and 300 ppm, respectively. Concentrations in commercial meat cuts from these same animals

showed toxaphene concentrations of $<$1.0 ppm to 7 ppm, respectively. Fatty tissues of a steer fed hay treated twice with 4 lb./ac. toxaphene contained 700 ppm, while lean meat was 35 ppm. Results of analysis of fat samples taken by biopsy from steers at 11, 19 and 23 weeks after feeding contaminated hay was terminated showed that most toxaphene had been eliminated by the eleventh week. Sheep retained more residues in commercial cuts and less in fat than steers. No residues were found in sheep slaughtered 7 months after termination of treating with toxaphene-treated hay (Diephuis and Dunn, 1949).

The toxicity of synthetic insecticides to dogs was reported by Batte and Turk (1948). The smallest dose of chlorinated camphene was 20 mg/kg. This did not produce death but did cause convulsions. Nunn (1952) mentioned that 12 of 14 dogs housed in kennels previously sprayed with 0.62 percent toxaphene in water were poisoned, of which 3 died. Poisoning resulted from drinking from puddles or from absorption through foot pads or other skin areas.

The inherent danger of using toxaphene for control of ectoparasites on mammals was pointed out by Shone (1961). Animals with very little body fat are far more susceptible than fat animals, and young animals more susceptible than adults.

Radeleff and Bushland (1950) discussed the acute oral toxicity of insecticides applied to livestock. Adult goats were all affected at oral administrations of 50, 100, 170 and 250 mg/kg. One of three goats died at 170 mg/kg, while all three subjects died when given 250 mg/kg. Three adult sheep were treated to each of these

4 dosage levels. None were affected at 50 mg/kg. All others were either affected or died. One death occurred at the 100 mg/kg level and two at 250 mg/kg. Some deaths occurred among suckling calves sprayed at 8, 4, 1.5 and 1 percent with single or double applications. Only 1 of 8 calves was affected at the 0.75 percent level despite being exposed to 8 applications. One steer was affected by an 8 percent dip, but only 1 of 20 animals showed such response at 4 percent. Goats were more sensitive - 2 deaths and 1 affected at 8 percent, but 3 were unaffected at 4 percent. Two sheep were affected and one died from the 8 percent dip. Two of three were affected but none died at 4 percent.

Eubank (1964) reported staggering and convulsions in 33 yearling calves from home treatment of fuel oil containing a liberal amount of toxaphene as a dermal application for tick control. All animals subsequently recovered following use of antidote and scrubbing with water and detergent.

Choudbury and Robinson (1950) fed 40 percent WP toxaphene to goats. Successive daily dosages of 25, 37.5, 50, and 75 mg/kg caused no effects in one goat. When dosages were increased to 100 mg/kg on day 9 and 10 and 150 mg/kg on day 11, death occurred. A second animal which received 100 mg/kg on days 1 and 2 and 150 mg/kg on day 3 died on day 4. A third goat which received a single 150 mg/kg dose died the next morning.

Bushland, et al., (1948) applied dips and sprays containing 1.5 percent toxaphene in attempts to induce pesticide poisoning

in cattle, sheep, goats, hogs and horses. Two series of tests were made, and treatments were applied eight times at 4day intervals. Observations were continued at least 30 days after last treatment. No apparent injury was noted.

III.C.1. Residues in Milk and Meat:

: Carter, et al., (1949), studied the chlorinated hydrocarbon content of milk from cattle sprayed for control of horn flies. The maximum and average amount of organic chlorine content from toxaphene in milk from two dairies was 0.6 and 0.1, and 0.2 and 0.1 ppm, respectively.

The effect of toxaphene on dairy cows was reported by Leighton, et al., (1951). A jersey cow which was fed 2.5 grams daily for 46 days plus 10 grams per day for an additional 14 days died with omental fat content of 67 ppm chlorine. Other animals at higher dosages showed chlorine residues in omental fat of 126 and 160 ppm. Normal chlorine content was considered to be about 5 ppm.

Feeding of toxaphene-treated hay to dairy cows for 112 days did not influence hay or grain consumption, milk or butterfat production, or alter the liver and kidney tissues. Toxaphene was found in the milk of cows receiving hay treated with 1,2 and 4 lb./acre in the ranges of 2.3 - 2.5 ppm, 3.9-4.3 ppm, and 8.3-18.2 ppm, respectively (Bateman, et al., 1953).

Claborn, et al., (1960) reported that strobane residues in the fat of steers after each of three spray treatments (2 percent solution) reached 20.4, 32.4 and 33.9 ppm, respectively. These

residues diminished to 0.8, 3.3 and 4.1 ppm in 14 weeks after last spraying. For heifers comparable figures were in the range 23.632.2 ppm after the sixth spraying and 1.63.9 ppm 14 weeks after spraying ceased. Toxaphene in fat of calves sprayed with 0.5 percent emulsion preparations in one case showed an average accumulation of 11 ppm after 12 successive weeks of spraying. This dropped to 2 ppm 6 weeks after spraying ceased. The spraying of cattle with 0.5 percent strobane emulsion or suspension provided additional data on residue buildup and elimination from fat. Each group included 3 steers and 3 heifers. Two weeks after the twelfth spraying the emulsion group averaged 6.6 ppm in fat which dropped to 2.8 ppm 6 weeks post spray. Comparable figures for the suspension spray were 5.9 ppm strobane in fat 2 weeks after the 12th spray and 2.6 ppm 4 weeks later (Radeleff, et al., 1951; Claborn, et al., 1953). Amounts of toxaphene found in fat of sheep and cattle during feeding period and after feeding was terminated are presented in Table III.C.1.

TABLE III.C.1

Toxaphene - Domestic Animals

Toxaphene residue storage (ppm) in the fat of cattle and sheep receiving known amounts in the diet

		Weeks feeding				Weeks after feeding stopped				
Animal	Dosage	4	8	12	16	4	8	20	32	36
3 ewes and	100									
3 wethers-Av.	ppm	22	21	25	20	12	0.5			

Table III.C.1 (cont'd.)

Animal	Dosage	Weeks feeding 4	8	12	16	Weeks after feeding stopped 4	8	20	32	36
3 steers and 2 heifers-Av.	100 ppm	26	34	33	38	14	3			
3 ewes and 3 wethers-Av.	25 ppm	2	2	3	8					
3 heifers and 2 steers	25 ppm	2	4	10	12					
Cattle (2) Av. Sheep (2) Av.	10 ppm	4								

The same author strudied strobane and toxaphene residues in milk from cows sprayed twice at 3-week intervals with 0.5 percent of both emulsions and suspensions. First day after the first spray residues of strobane in milk were 0.61-0.87 ppm. These declined steadily each sampling date thereafter. On post-spray day 14 the milk residues were 0.0-0.13 ppm. On the second day after the second spray treatment, milk residues were in the range 0.55 - 0.69 ppm. After 14 days milk residues were 0.0-0.4 ppm. The first day after toxaphene treatment residues of toxaphene in milk were 0.55-0.82. Twenty-one days later these residues in milk declined to 0.03-0.21 ppm.

Post-second spray data showed 2nd maximums of 0.51, 0.59, 0.92 and 0.70 ppm. Three weeks after second treatment these values dropped to 0.06, 0.05, 0.04 and 0.0 ppm, respectively.

Strobane and toxaphene were sprayed daily (2 cows on each test) for 21 days with 1 oz. of 2 percent oil solutions. Strobane reached maximum values in milk of 0.30 and 0.39 ppm which dropped

to 0 and 0.02 fourteen days after spraying ceased. Toxaphene reached maximum figures of 0.32 and 0.50 ppm 3 days after spraying started but dropped to 0.07 and 0.06 on post-spray day 21.

Sixteen lactating dairy cows were placed on dairy rations containing 0 to 20 ppm of toxaphene for 77 days. Their milk was sampled periodically and analyzed for toxaphene by a total chloride procedure. It was estimated that toxaphene concentrations of less than 1.0 ppm in the daily ration resulted in less than 0.03 ppm of toxaphene in the milk. Uncontaminated milk was produced by all but one animal within 14 days after taken off toxaphene diets. Maximum residues obtained in milk from the 20 ppm/daily intake diet were 0.26 ppm on the 49th day of test whereas those fed 15 ppm daily reached 0.34 ppm on the same day (Zweig, et al., 1963).

Data presented in table III.C.2. show that toxaphene given in feed to cows at levels of 20, 60, 100, and 140 ppm was secreted in milk at all dosage levels. Highest level recorded was 2.51 ppm at the 8th week of 140 ppm dosage. There was a rapid decrease in the residue to the level of 0.1 to 0.3 ppm the first week after feeding ceased; further decreases were at a slower rate for animals fed more than 20 ppm. Toxaphene residues in omental fat in cows given treated feed daily ranged from 8.4 to 24.3 ppm for the three highest dosage levels at the end of the 8-week feeding period (Claborn, et al., 1963).

TABLE III.C.2

Toxaphene in milk from cows fed varying levels of toxaphene in the diet

Dosage (ppm)	No. of Cows	Toxaphene in milk (p.p.m.)										
		Weeks of feeding							Weeks after feeding ceased			
		1	2	3	4	5	6	7	8	1	2	3
20	3 Av.	0.20	0.26	0.26	0.36	0.33	0.37	0.27	0.23	0.07	0.02	-
60	3 Av.	0.56	0.61	0.75	0.68	0.63	0.71	0.49	0.48	0.13	0.10	0.0
100	3 Av.	0.87	0.01	1.01	1.15	0.97	0.96	0.86	0.91	0.15	0.13	0.1
140	3 Av.	1.44	1.67	1.80	1.89	1.50	1.64	1.71	1.82	0.32	0.40	0.2
Control	2 Av.	0.00	0.01	0.00	0.06	0.16	0.00	0.00	0.00	0.00	0.00	0.0

From Claborn, et al., 1963

The fate of organochlorine pesticides during processing of milk into dairy products was studied by Li, et al., (1970). Residue analyses of these dairy products and by-products indicated pesticide stability for ordinary processing operations and slight change in residue content after storage at refrigeration and room temperatures for six months. Concentrations of toxaphene increased slightly during storage of milk and milk products, suggesting that a re-orientation occurred. Toxaphene (100 percent) was fed daily at the rate of 15 mg in acetone/kg and residue content of milk analyzed 10 days after initial treatment. Fat from ten samples of raw whole milk contained 20.8 to 30.1 ppm.

The amounts of toxaphene found by Roberts and Radeleff (1960) in the fat of hogs sprayed with a 5 percent toxaphene emulsion are shown in the Table III.C.3. No toxaphene was present in the

omental fat at either 4 or 6 weeks after one or two sprayings of toxaphene. Toxaphene was present in renal fat 4 weeks after treatment, but not after 6 weeks. The residues were greater in the animals that received two treatments. On the basis of these results, it appears that meat from toxaphene-treated hogs is safe for human consumption if the animals are slaughtered 6 weeks after spraying once or twice with 0.5 percent toxaphene.

TABLE III.C.3

Toxaphene found in the fat of hogs, calculated from organic-chlorine content and corrected for controls.a

Weeks After Treatment	Number of Animals	Omental Fat	Renal fat
	One Spray		
4	3	-0.21	0.81
6	3	-1.42	-0.18
	Two Sprays		
4	3	-0.40	1.14
6	2	-1.93	-0.36
Control	6	4.60	3.96

a Negative values indicate less organic chlorine than was found in the control sample.

The effect of injection of toxaphene on hatchability of fertile chicken eggs was investigated by Smith, et al., (1970). Toxaphene at 1.5 mg/egg injected with a corn oil carrier into the albumin prior to incubation resulted in no decrease in hatchability. Similarly, strobane at doses up to 6 mg per egg produced no apparent deleterious effects.

Sherman and Ross (1961) studied the acute and subacute toxicity of insecticides to chicks and reported that the acute oral LD_{50} of strobane to female chicks was 139 mg/kg.

III.D. Effects on Beneficial Insects:

The occurrence of some unusual insect outbreaks after application of pesticides to control cotton pests suggested that these materials might be detrimental to the natural enemies of the target pests (Newsom and Smith, 1949). A study area received 2 applications of 20 percent toxaphene dust plus 40 percent sulfur at 11.4 lbs./ac./application and another site 6 applications of 10.6 lbs./ac. each. Toxaphene was more destructive to the big-eyed bug, Geocoris punctipes, and the flower bug, Orius insidiosus, than BHC, DDT, calcium arsenate or chlordane but did not significantly reduce the Coccinellidae (lady beetles).

Campbell and Hutchins (1952) conducted tests on the ladybeetle, Scymnus sp., which showed 72 percent mortality in 72 hrs. and 84 percent at 96 hrs. at a 2.5 lb./ac. application rate. Two other species were reduced 85 and 61 percent 96 hrs. after dust application. Hemipterous insects in both laboratory and field tests were more seriously affected than the coccinellids.

The repellent properties of toxaphene dust to the alkali bee (Nomia melanderi) were studied by Menke (1954). Application of 15 percent toxaphene dust at 30 lbs./ac. to blossoming alfalfa had little effect on alkali bee activity.

The total population of insects and spiders occurring in experimental cotton fields near Waco, Texas was studied in relation to effects of various insecticide treatments. Toxaphene-sulfur dust applied after two

early-season toxaphene-DDT sprays gave the lowest population of injurious insects and the highest population of beneficial insects (Glick and Lattimore, 1954).

Gaines (1954) studied the effect on beneficial insects and spiders of toxaphene 20 percent-sulfur 40 percent applied for cotton insect control. An early July treatment (8 lbs./ac.) was followed 3 weeks later by 10 more applications 4 or 5 days apart (2 at 10 lb./ac.; 4 at 12 lbs./ac.; and 4 at 15 lbs./ac.). After the second to fourth application of the regular boll weevil control program, beneficial insect and spider populations were practically eliminated. These included lady beetles, flower bugs, lace wing, Geocoris, assassin bugs, spiders, and syrphids. A follow-up study verified these findings (Gaines, 1955).

A test was conducted in the Panhandle area of Texas on effects of toxaphene (1, 2, 3 or 4 applications sprayed at 2.1 lbs. a.i./ac.) on insect control and seed yields. All treatment helped control lygus, leafhoppers and thrips while seed yield gained 2.7 to 22.8 percent. Toxaphene had very little effect on populations of pollinating insects (Daniels, 1955).

The covergent lady beetle, striped collops and spotted lady beetle are important insect predators on pests affecting cantalope and alfalfa near Phoenix, Arizona. These species, held for 24 hours on plants treated with 10 percent toxaphene dust, showed mortalities of 12, 32 and 36 percent, respectively (Harries and Valcarce, 1955).

Experiments were conducted to study the control of insect pests of hairy vetch. A single treatment of 2 lbs. toxaphene plus 0.25 or

0.125 lb. demeton provided seasonal control of lygus bugs and pea aphids with minimum damage to pollinating insects (Weaver and Garner, 1955).

The beneficial insects in California cotton and alfalfa fields play an important role in the natural control of insect pests. Studies were made to evaluate effects of pesticides on predators of the Genera Orius, Geocoris, Nabis, Chrysopa and Hippodamia. A toxaphene-DDT combination was listed highly toxic while toxaphene alone (3.5 lb./ac.) was considered moderately toxic (van den Bosch, et al., 1956).

Stern, et al., (1959) also conducted field tests to determine the relative toxicity of pesticides to certain entomophagous insects which help control field crop pests in California. A DDT-toxaphene mixture (1, 3 and 2.6 lbs., respectively) proved extremely toxic to Hippodamia convergens, Geocoris spp., Orius sp., Chrysepa spp., Nabis ferus, Sinea diadema, and to syrphids. Toxaphene alone (2.7 lb./ac.) was less toxic than DDT or the DDT-toxaphene mixture.

Sprays containing parathion, malathion, demeton, endrin or toxaphene applied to alfalfa in Oklahoma caused marked reductions of the total arthropod populations. Reductions were greater for the phytophagous species than for entomophagous species. Effects on certain predators created favorable conditions for prey species which later became more numerous in the sprayed plots than in the untreated checks. Toxaphene at 3 lbs./ac. was generally less effective than 1/4 to 1/2 lb./ac. of the other chemicals (Fenton, 1956).

Laboratory tests were made of the toxicity of several insecticides to beneficial insects on cotton (Burke, 1959). Toxaphene-DDT was fourth least toxic among 10 formulations using the petri-dish method against Hippodamia convergens, and second least toxic when applied topically. Median LD_{50} was 1.069 mg/g body weight. Toxaphene was the least toxic material tested against Orius insidiosus.

Initial and long term effectiveness of soil applications of toxaphene was determined in the field against Hippolates collusor gnats in California. Toxaphene EC 8 at 17.2 lbs./ac. provided 77 percent control after one month, 41 percent after one year, and 13 percent control after two years (Mulla, 1961). Field studies of toxaphene used as a soil toxicant to control the Mexican fruit fly were conducted by Shaw and Riviello (1961) during the rainy season at Cuernavaca. Toxaphene 60 EC applied at 50 lb./ac. gave 30, 12, 13, 18 and 6 percent mortality at 1, 58, 135, 219 and 289 days after treatment.

The contact toxicity of 61 pesticides was determined by exposing 5 parasitic hymenopterous and 6 predatory coccinellids to day-old residues at rates commonly found on orchard crops (Bartlett, 1963). Toxaphene persistence was rated medium to high. Toxicity ratings were given in three categories: H (high)-LT_{50} $<$ 24 hrs.; M (medium)-LT_{50} $>$ 24 hrs. and $<$ 100 hrs.; and L (low)-LT_{50} $>$ 100 hrs. With these parameters, toxaphene rated M-H(1) or H(5) on Hymenoptera species. It was

less toxic to the coccinellids with four rated M, and one each listed L-M and L. Bartlett (1966) later discussed the effects of these toxicants as stomach poisons on two species each of parasitic Hymenoptera and predatory coccinellids. Toxicity here was expressed as high if LT_{50} <1 day; M if >1 and <4 days; L if >4 days; and 0 if none. Toxaphene at low concentrations in honey gave figures of 0,0,0-L and 0-M; at high concentrations results were 0,0-L and L-M twice.

Toxicity of 60 pesticides to eggs, larvae, and adults of green lacewing, Chrysopa carnea, was tested at dosages similar to those used in orchards by Bartlett (1964). Toxaphene spray had no effect upon eggs, and LT_{50} ratings of M-H on larvae, and H (<24 hrs.) upon adults.

Adult lady beetles, Coleomegilla maculata, were treated topically with toxaphene-DDT, and toxaphene alone to evaluate effects on reproductive and survival potentials (Atallah and Newsom, 1966). Toxaphene caused a decrease in longevity and prevented oviposition; the diapausing beetles withstood higher doses than active beetles. The experimental population was heterogenous in its response to toxaphene. Toxaphene-DDT mixture exhibited strong synergistic action, decreased longevity, and decreased reproduction to about one third of controls. It had no effect on survival potential of the F_1 generation.

Insecticides resistance in Bracon mellitor, a parasite of boll weevil, was studied in Mississippi by Adams and Cross (1967). Potential resistance was determined by treating each of 5 test groups for 5 or more

generations. Four fold increases in tolerance were noted in groups treated with DDT, carbaryl and methyl parathion. Treatment with equal parts of DDT and toxaphene showed resistance 8 times that of the original generation. One group treated only with toxaphene showed no significant increase in tolerance.

Effects of insecticide applications in Texas on beneficial insects and spiders were recorded by Walker, et al., (1970). Results showed that at dosages appropriate for cotton fleahopper control, toxaphene reduced populations of beneficial arthropods. Beneficial levels tended to resurge after treatments were stopped, but remained somewhat lower than the untreated controls as shown in Table III.D.1.

TABLE III.D.1

Totals per acre of spiders and three beneficial insects following toxaphene application

Treatments (Two insecticide applications) 6-17- and 6-24-26-				
	three beneficial insects*		Spiders	
Sampling Dates	Control	Toxaphene 1 lb.?C. (twice)	Control	Toxaphene 1 lb./ac. (twice)
6/27 - 7/1	5950	1248	5937	1758
7/7 - 7/10	4539	3474	6799	2983
7/14 - 7/18	9215	5351	9911	4833

*Hippodamia convergens, Orius insidiosus and Scymnus spp.

III.D.1. Effects on Bees:

The choice of an insecticide to be used on legume seed crops in bloom should be determined by its hazard to bees as well as the economic effectiveness in controlling harmful insects (Lieberman, et al., 1954). Tests were conducted in 1950, 1952 and 1953 to learn effects of various chemicals on honey bees from applications made on seed alfalfa before 7:00 A.M. or after 7:00 P.M. On the basis of 10 percent mortality being the limit for sanction, toxaphene was classified as safe.

The toxicity of agricultural chemicals was studied by Eckert (1949). The LD_{50}, as determined by feeding caged bees known quantities of toxaphene in 20 percent sugar sirup, was 22.0 µg per bee in 72 hours. Stomach poison time was 5 - 24 hours, and contact poison in 1 - 3 hours. Weaver (1953) found toxaphene, both as a dust and a spray, to be the least toxic for bees of nine compounds tested on cotton. It showed only slight toxicity and repellency resulted from applications to cotton.

Jones and Connell (1954) reported on oral LD_{50} of 39.8 µg for 24 hrs. Low toxicity of toxaphene was observed to bees in both stomach and contact poison tests. Atkins and Anderson (1954) rated toxaphene as moderately toxic to bees. Mortality of bees from exposure to 200 and 400 mg of toxaphene dusts after 72-hr. was only 30 and 21 percent, whereas mortality from numerous other compounds over a shorter time span was 100 percent. Further work by Anderson and Atkins (1958a) confirmed the low toxicity of toxaphene to bees. They advised correct timing and dosage and that toxaphene

should not be applied directly on bees in the field or at the colonies (1958b).

The effect on honey bees of toxaphene and strobane applied to white clover pasture in New Zealand was recorded by Palmer-Jones, et al., (1958). Toxaphene dust and spray when applied at 5 lb. a.i./ac, did not cause bee mortality or adverse effect upon brood. Strobane caused slight mortality of field bees but bees at the hive and brood were unaffected.

Toxaphene resistance in honey bees was studied by Atkins and Anderson (1962). The number of hours required for a 10 percent toxaphene dust to kill 50 percent of the test population increased from 140 hours in 1952-1953 to 560 hours in 1961. In addition, 20 and 40 percent toxaphene dusts, used concurrently, caused no mortality above the normal check bee level after 96 hours.

The contact toxicity of toxaphene to honey bees in Egypt was investigated by Ibrahim, et al., (1967). Toxaphene application, at the rate of 3, 4 or 5 liters per feddan (1.038 ac.), did not cause mortality to honey bees 6 hours after exposure.

Todd and Reed (1969) indicated that pollen and nectar by honey bees gathering from an alfalfa field sprayed with 3 lb. toxaphene and 0.5 lb. endosulfan was reduced by one half. Pollen collection remained suppressed for several days.

Commercial applications of toxaphene, DDT and Dylox at 4, 2 and 1 lbs. per acre caused a reduction in bee visitation for 2 days but bee kills in excess of pretreatment levels were not detected (Atkins, et al., 1970).

Mortalities in Egypt among caged honeybees exposed to cotton plants sprayed in the field with toxaphene, DDT-lindane and dieldrin were recorded by Wafa, et al., (1963). An average of counts made for 15 days after spraying showed the following losses: control - 2.7; toxaphene - 7.79; DDT-lindane - 22.24; and dieldrin - 57.41 percent. When toxaphene 60 percent e.c. was applied at 3.5 l/ac., maximum mortality, which was 62.9 percent the day after spraying, did not exceed 10 percent during the balance of the 15-day test. In another study with bees collected in the field over an 8 day period post-spray mean mortalities of 4.42 percent occurred in the control area and 38.94 percent in the toxaphene-treated field.

Percentage mortality of honeybees at successive intervals after direct application of 10 percent toxaphene dust was 21 at 6 hours, 89 at 12 hours and 98 at 18 hours (Anderson and Tuft, 1952).

Weaver (1949, 1950, 1951, 1952) commented on the toxicities of various organic insecticides to honeybees. At a temperature of 94°F. the oral MLD to toxaphene was 0.27778 mg/gm body weight. The safest of field-tested insecticides in dust form was a mixture containing 20 percent toxaphene - 40 percent sulfur. Eight weekly

field applications of this mixture in dosages ranging from 10 - 40 lbs./ac., killed only 0.77 percent of the bees. Sprays were considered more toxic than dusts when applied directly to bees. Small colonies of bees were placed in screened areas 36 feet long, set up over two rows of cotton. Toxaphene (20 percent) did not repell the bees and was not highly toxic. Toxaphene produced a higher mortality on the second rather than any other day. Total mortality during the season was 11.6 percent.

III.E. Occurrence in Water

Routine monitoring (Brown and Nishioka, 1967; Lichtenberg, et al., 1970; Manigold and Schultze, 1969; and Wershaw, et al., 1969) of waters of the United States has not indicated the presence of toxaphene. One reason may be that the amount required for detection in routine screening analyses is greater than that of most pesticides reported. This point was brought out by Weaver (1965) in his survey of chlorinated hydrocarbon pesticides in major U.S. river basins. For example, toxaphene detection was beyond the scope of the procedure used although it is one of the more heavily used pesticides. Similarly, Schafer, et al., (1969) did not detect toxaphene during their survey of pesticides in drinking water from the Mississippi and Missouri Rivers. Lichtenberg (1971) states that the minimum toxaphene concentration required for recognition in his monitoring of 1 liter water samples is 1 µg/l, although lesser amounts may be determined in samples in which presence of toxaphene is anticipated.

Monitoring of agricultural pesticides in sediment and water in the Mississippi River delta by Agricultural Research Service, USDA (1966) showed a few samples with trace amounts of toxaphene in water. However, 18 of the samples of sediment collected from surface water sources at various sites contained 0.04 to 7.1 ppm strobane/toxaphene. Surface water residues were from 0.1 to 8.65 ppb in 4 positive samples. Three positive quick runoff samples contained 0.9, 1.17 and 2.48 ppb, and a sample from one well contained 5.0 ppb.

When 26.8 kg/ha of toxaphene was applied to cotton during the 1969 growing season, natural runoff was checked between July 11, 1969 and January 5, 1970. Of 26.8 kg/ha of toxaphene applied, 0.36 percent was detected in runoff, and 75 percent of the toxaphene in runoff was in the sediment fraction. When DDT and toxaphene were applied to the same plot at seasonal rate of 13.4 and 26.8 kg/ha, respectively, 1.03 percent of the DDT and 0.61 of the toxaphene were found in runoff. Toxaphene residues in pond water from adjacent foliar applications varied from <1 ppb before spraying to 65 ppb about midseason (Bradley, et al., 1972).

Insecticide contamination in tile drainage effluent from irrigated land in the San Joaquin Valley of California was investigated by Johnston, et al., (1967). Relatively small amounts of pesticides were found in tile drainage effluent, but higher concentrations

were found in effluent from open drains where both surface and subsurface drainage waters were collected. Traces of residues were found in the irrigation water applied to tile drained farms. When the concentration factor is considered, i.e., depth of irrigation water applied/depth of drainage water removed, on a unit basis, the total quantity of insecticide residues in tile drainage effluent did not exceed and was generally less than the total quantity of residue applied in the irrigation water. Tile effluent averages of toxaphene from one plot were 50,175, and 550 ppb for first, second and third floodings, respectively. From a second plot levels were 500, 50 and 0 ppb, and from a third area only an initial first flooding residue of 100 ppb was detected. Toxaphene was detected in 13 of 66 samples of tile drainage effluent in concentrations varying from 0.13 µg/1 to 0.95 µg/1 and averaging 0.53 µg/1. Sixty of 61 water samples from surface drains that collected surface and subsurface water were positive for toxaphene. Concentrations varied from 0.01 µg/1 to 7.90 µg/1 and averaged 2.01 µg/1. The predominant residues found in surface water were DDT/DDD and toxaphene. The average concentration of toxaphene was higher than any other chlorinated hydrocarbon insecticide and it was found most frequently.

Annual reports of the San Joaquin District, California Department of Water Resources (1963-1969) presented data on toxaphene occurrence in Central Valley tile drainage effluent, in surface waste water drains from irrigated areas, in other Central Valley surface water,

and in bay and ocean water. Twelve percent of 422 water samples from San Joaquin Valley tile drainage systems contained toxaphene in concentrations ranging from 0.02 µg/l to 1.26 µg/l. Forty-eight percent of 447 Central Valley agricultural surface water drains contained concentrations within the range 0.04 - 71.0 µg/l.

Surface water flows directly into drains under some conditions (Beck, 1971). Toxaphene was found in 12 percent of 712 other Central Valley surface waters in concentrations ranging from 0.02 µg/l to 0.93 µg/l, and in 4 percent bay and ocean water samples in concentrations 0.03 µg/l to 0.06 µg/l.

The amount of toxaphene in sediment undoubtedly reflects the degree of useage as well as watershed soil management practices. In California Bailey and Hannum (1967) found higher amounts of toxaphene in sediment than in water (Tables III.D.1 and III.D.2.). Generally, sediments of smaller particle size had higher pesticide concentrations that those of larger size.

TABLE III.E.1.

Toxaphene in California Sediments (µg/l)*

Source	Max.	Min.	Average
Streams			
Sacramento River at Walnut Grove	130	5	57
Little Connection Slough at Altherton Road	—	—	170
San Joaquin River at Antioch	—	—	140
Bays			
San Pablo Bay at Pt. San Pablo	—	—	110
So. San Francisco Bay at San Mateo Br.	110	88	99

TABLE III.E.1 (cont'd.)

Source	Max.	Min.	Average
Agricultural Drains			
Reclamation District #108 Drain	--	--	210
Staten Island Drain	--	--	110
Roberts Island Drain at Whiskey Slough	--	--	380

* Bailey and Hannum, (1967). The method of reporting concentration is unique and not relatable to µg/g of sediment in the usual manner. Concentrations are reported as parts of pesticide per parts of wet sediment. A representative location of the sample was dried and a moisture content determination was made. The pesticide concentrations were then adjusted to parts per parts of dry sediments from the relationship $\frac{Cs=100C-CwSm}{Sd}$ in which Cs=dry weight pesticide concentration in overlaying water sample; Sm=percent soil moisture in sample; and Sd=percent dry material in sample.

TABLE III.E.2.

Toxaphene Concentration in California Surface Water (µg/l)*

Sampling Station	Max.	Min.	Average
Sacramento River at Walnut Grove	0.40	0.03	0.10
Mokelumne River at Highway 99	--	--	0.04
Little Connection Slough at Altherton Road	--	--	0.16
Delta Mendoto Canal at Head	0.12	0.03	0.08
San Joaquin River at Antioch	0.32	0.05	0.15
Suisan Bay at Martinez	0.09	0.05	0.06
San Pablo Bay at Pt. San Pablo	--	--	0.08
San Francisco Bay at Berkeley Pier	0.23	0.03	0.13

TABLE III.E.2. (cont'd)

Sampling Station	Max.	Min.	Average
So. San Francisco Bay at San Mateo Br.	--	--	0.26
San Joaquin River at Vernalis	0.93	0.02	0.26
San Joaquin River at Fremont Ford	0.46	0.04	0.13
Salton Sea near North Shore	0.40	0.05	0.14
Alamo River	0.65	0.30	0.47
All American Canal at Alamo River	0.08	0.04	0.06

* Bailey and Hannum, (1967). Sample size 5 liters; analytical method, microcoulometric gas chromatography; sensitivity of method, 0.02 to 0.05 µg/l.

Bailey and Hannum (1967) analyzed more than 630 samples taken in California of surface waters, agricultural drainage, sediments and aquatic organisms. Although toxaphene was recovered at 14 of 20 sampling stations, amounts found were less than 1 µg/l.

Largest amounts of toxaphene were found in water from agricultural drains. Temporal distribution was related to agricultural drainage practices and to runoff from heavy rainfall.

Nicholson, et al., (1964) investigated the seasonal distribution of toxaphene in the Flint Creek system of Alabama using the carbon adsorption method. The mean seasonal recoveries of toxaphene from the summer of 1959 through the fall of 1960 ranged from 29 to 140 ppt.

Grzenda and Nicholson (1965) studied soil from cotton field, water and river bottom sediments, and bottom fauna and fish at Flint Creek, Alabama, to determine the distribution of toxaphene, among biotic and abiotic components of a stream system. Amounts of toxaphene found in

river water varied from 30 to 140 ppt. No toxaphene was recovered from river bottom sediment. This was reflected in infrequent occurrence of toxaphene in bottom fauna. All fish samples, however, contained toxaphene.

Nicholson, et al., (1966) studied a 400/sq. mile cotton producing area in the Flint Creek watershed in Alabama. During the 6 1/2 year study period the annual cotton acreage varied from 12,700 to 16,500. Water samples of 2,000 to 10,000 gal. were processed through activated carbon adsorption units for recovery of insecticides. Analysis was by gas chromatography.

A peculiarity of the method was that water was extracted over periods 1 to 2 weeks thus averaging peak occurrences. The extended sampling period insured against missing toxaphene if its presence was discontinuous. The values were not absolute because of possible incomplete extraction from water and recovery from carbon. The sampling devices were operated almost continuously for the entire study period. The authors attributed the presence to toxaphene in Flint Creek primarily to surface runoff. Mean toxaphene residue recoveries in water in ppt by season were: summer - 15-140; fall - 23-67; winter - 5-111; and spring - 1-61 ppt.

Nicholson, et al., (1966) also showed the relative importance of sediment versus solution in the transport of toxaphene, DDT and BHC in Flint Creek, Alabama. Suspended sediment seemed less frequently involved in toxaphene and BHC transport than in DDT transport. This suggests the affinity of solid substrates for toxaphene in low water concentrations is less than for DDT. This contention is supported by frequent detection of toxaphene in clarified and treated municipal drinking water while DDT rarely was found.

Barthel, et al., (1966) studied agricultural chemicals contained in stream bed materials of the Lower Mississippi River. Toxaphene/Strobane was found only in one 5-mile stretch in the vicinity of West Memphis, Arkansas. Amounts detected varied from 0.10 to 0.60 ppm and were attributed to upstream agricultural usage.

III.F. Occurrence in Air

The use of agricultural chemicals for pest control has caused undesirable residues in adjacent areas. Extent of contamination is related to the method of application with aerial spraying or dusting probably creating the greatest hazards. As early as 1945-46, losses of dairy animals in California were attributed to drifting calcium arsenate. Drift problems became more acute with the increase in the use of herbicides such as 2,4-D.

Akesson and Yates (1964) studied the drifting of dust and spray formulation. Emulsions were applied at the rate of 4 lb./ac. toxaphene as compared with 27 pounds of dust per acre which contained 4 lb. toxaphene. During trials wind velocity was 3-4 mph. Amounts of toxaphene detected at all points down wind was 4 to 10 times higher from the dust than from the spray.

A study of airborne particulate pesticides in urban atmospheres was conducted by Tabor (1965). Samples were collected in eight agricultural communities and in four communities with active insect control programs. Ambient concentrations of toxaphene were found in 3 of 5 samples of air from Newellton, Tensas Parish, Louisiana in

amounts as large as 15 ng/m^3. Extensive cotton plantings were located on three sides of the community. Data also were obtained for an area completely surrounded by cotton fields. There 6 of 15 samples from Leland, Washington County, Mississippi, contained toxaphene ranging from 1.2 to 7.5 ng/m^3 (Tabor, 1966).

The effects of simulated rain and dew on the toxicity of ULV sprays of Strobane to the bollworm and boll weevil in Texas were studied by Nemec and Akesson (1969). The available data indicate that the toxicity of the pesticide to these two plant pests, when used as ULV sprays of emulsifiable or water-miscible formulations, may be reduced significantly if subjected to rain or applied to plants wet with dew. A strobane-methyl parathion mix (1 lb. ai each/ac.) gave 100 percent kill to bollworm larvae through 72 hours without rain. Simulated rain of 1.0 inch applied to plants 1 hr. after insecticide treatment caused a kill of 33 percent in 48 hours. With an Azodrin - Strobane mixture (0.5 - 0.25 lb. ai/ac., respectively) a 95 percent kill was obtained with no rain and only 28 percent kill after 48 hours with rain exposure as given above.

Stanley, et al., (1971) set up a pilot study for measuring the extent of atmospheric contamination by pesticides at nine localities in the U.S. Samples were analysed for 19 pesticides and metabolities. Only DDT was detected at all localities. Toxaphene levels in three samples taken at Stoneville, Mississippi were 1110,151 and 81 ng/m3. Selected results for the first day of each week of sampling for Stoneville

are given in Table III.E.1. Maximum toxaphene levels found at three additional sites were: Dothan, Ala. - 68.0 (11); Orlando, Fla. - 2520 (9); and Stoneville, Mississippi - 1340 (55) ng/m3. Figures in parentheses indicate number of samples containing detectable amounts.

TABLE III.F.1

Toxaphene Found in Air Samples from Stoneville, Mississippi The First Day of Each Sampling Week

Date	Toxaphene level, ng/m3
August 14-15	283
August 21-22	373
September 11-12	701
October 2-3	161
July 1-2	68
July 15-16	116
July 29-30	62
August 12-13	135

III.G. Effect on Plants

Study of insecticide residues on forage crops is of importance since the levels remaining at time of harvest may be stored in animal fat or

secreted in the milk. George, et al., (1967) studied residue persistence of toxaphene e.c. on red clover at application rates of 1, 2, 3, 4 and 6 lb. actual ingredient per acre. Samples taken 69 days after last application of 1, 3, 4 and 6 lb./ac. contained $<$0.1 ppm, while the 2 lb./ac. rate residues were $<$0.1 to 0.29 ppm.

Screenings from Ladino clover seed grown on fields which had been treated with toxaphene (2 lb./ac. May 28 plus 3 lb./ac. on July 5) and harvested 30 - 60 days later, were analyzed as composite samples. Subsequently the composites were separated into 13 fractions. The composites contained 21.1 ppm. Seventy percent of this toxaphene occurred in clover chaff and soil (Archer, 1970). In another study, Archer (1968) reported 65.7 ppm toxaphene on ladino clover seed screenings. Toxaphene residues in alfalfa pellets produced from 75 percent seed crop threshings and 25 percent screenings varied from 6.3 to 16 ppm. Toxaphene residues in lucerne and clover as determined by Adamovic and Hus (1969) ranged from 0.5 to 200 ppm.

The rate of disappearance of toxaphene used on birdsfoot trefoil in Vermont was reported by MacCollum and Flanagan (1967). Toxaphene residues (day 0-5.03 ppm) diminished rapidly but were still detectable (0.15 ppm) 48 days after application. Seed production from the treated plot was 6 percent less than the check area.

In Montana treatment of alfalfa with water emulsion caused greater toxaphene residues than treatment with the dust formulation (Laakso and Johnson, 1949). Losses of toxaphene up to 72.9 percent 31 days after application were noted following water emulsion treatment. Rate of loss was greatly decreased after baling and storage.

Alfalfa sprayed with large concentrations of toxaphene (250 mg/l) was air dried, sunlight dried, and dried under ultraviolet light. Maximal residue losses which were 19 percent, 54 percent, and 46 percent, respectively, occurred approximately within 7 days after application and plateaued thereafter. No photochemical degradation products were detected (Archer, 1971).

Osborn, et al., (1960) studied persistence of toxaphene residues on forage under sprayed pecan trees. Initial deposits of 488-672 ppm resulted from two spray applications of 6 lb. of wettable powder (40 percent toxaphene) per 100 gal. made at two week intervals. Residues ranged from 69 to 126 ppm after weathering 2 weeks and 23 ppm after 10 weeks.

Residues in vegetable crops following soil applications of toxaphene were measured by Muns, et al., (1960). Sugar beets, radishes, potatoes and table beets grown in soil treated with 3 lb./ac. contained 0.0-0.4 ppm when harvested 5 to 18 weeks after treatment.

Brett and Bowery (1958) studied toxaphene residues on snap beans, tomatoes, and collards dusted when ready for harvest at 30 lb./ac. Toxaphene residues persisted for at least 12 days

on collards and snap beans. There was no detectable residue on tomatoes after the ninth day. Bean residues decreased from 8.1 ppm on day 0 to 1.52 ppm on day 12; residues on collards were 168 ppm on day 0 and 4.9 ppm on day 13; on tomatoes, 4 ppm on day 0 and 0.15 ppm on day 9.

Toxaphene residues on cotton plants during a 15-day period after a third spraying were determined (El Sayed, et al., 1962). Amounts of toxaphene lost at 5, 10 and 15 days after treatment were 39.3, 68.2 and 81.9 percent, respectively.

Roark, et al., (1963) studied the effect on cotton caused in Mississippi by different pesticide formulations which were applied during the first 6 weeks of growth. Methyl parathion delayed initiation of fruiting branches and production of floral buds. However, there were no obvious effects on plant metabolism from treatment with toxaphene. Similar results were reported by Mistric, et al., (1970) from North Carolina. Methyl parathion caused a 510 day delay in squaring and consequent delay in maturity whereas mixtures containing toxaphene caused neither delayed growth nor decreased yield.

Rates of growth were studied with plants maintained in quartz sand. Effects were studied of insecticidal soil residues on plant growth in quartz sand fortified with 30 ppm toxaphene. With corn roots, growth was 87 percent of check plot and the stem was 88 percent. With peas from toxaphene treated soil root growth

was 108 percent of the check plots and stem growth 114 percent. Effect of 30 ppm toxaphene on respiration of root tips expressed as µl oxygen uptake per 100 mg fresh weight in percent of control was: corn-93.9 percent; oats-78.8 percent; peas-99.0 percent; and cucumber-119.3 percent. In general, chlorinated hydrocarbons inhibited plant growth less than the organophosphates or carbaryl (Lichtenstein, et al., 1962).

The mixing of several pesticides for use in a single application against different pests is a common practice among apple and pear growers. Kiigemagi and Terriere (1963) checked persistence of residues on pears in Oregon where toxaphene at 3 - 4.8 lb./ac. was applied in a mixture containing DDT. The harvest residue of toxaphene was 0.66 ppm as compared to the FDA tolerance of 7.0 ppm. Minimum time interval between last spray and harvest for toxaphene to reach 1/3 of tolerance was calculated at 28 days.

The inheritance of phytotoxicity of toxaphene to oats was examined by Gardenhire and McDaniel (1970). The reaction was found to be controlled by a single major gene, with susceptibility conditioned by the dominant allele. Toxaphene effect appeared to be localized and caused discoloration and eventual death of leaf tissue contacted by the spray. New growth appeared normal. Toxaphene and not the solvent carrier appeared to cause the damage.

Control of soil insects attacking vegetables during early growth is carried out in Trinidad by application around individual

seedlings (Hagley, 1965). Applications of 1.4 and 14 lb. ai/ac. were made to 2 - to 3-week-old seedlings. No adverse effects occurred after 4 weeks with the 1.4 lb./ac. rate. The high treatment rate reduced the growth rate of cauliflower and tomato seedlings. Toxaphene reduced the size of chinese cabbage seedlings but did not affect root development. The high rate of treatment caused severe marginal and interveinal chlorosis and necrosis of the lower leaves, and resulted in death of one third of the tomatoes in the second and third weeks of growth.

Beckham (1965) studied the response of cotton plants to various pesticides. While his experiments with toxaphene included this compound only when mixed with DDT, there appeared to be no significant difference as to insect control, plant growth or average yield.

Residues of toxaphene found on corn plants treated for European corn borer in Iowa were analysed by Fahey, et al., (1965). Toxaphene (65 percent EC) applied to corn plants at 1.5 lb./ac. deposited initial residues of 1.1 to 11.9 ppm. These residues decreased to less than 2 ppm 30 days after treatment. Residues from granular material also applied at 1.5 lb./ac. dropped from 6.9 ppm on day of application to 2.0 on day 30 and 1.7 ppm on day 65 post-treatment.

One of the earliest studies on the effects of chlorinated camphene (toxaphene) on plants was reported by Morrison, et al., (1948). An experimental plot was treated at the rate of 27.5 lb. ai/ac. Following this treatment twenty-nine different vegetables,

some seeded and others transplants were planted on test plot. Plant injury was not observed throughout the season. Cullinan (1949) reported on the general soil stability of chlorinated hydrocarbons but found that toxaphene does break down under certain conditions. Toxaphene will depress growth of some seedling plants when applied to the soil at 25 lb./ac. The toxicity of toxaphene tended to decrease with time. The compound was apparently affected by soil fungi and bacteria. Foster (1948) also noted that toxaphene tended to decompose in soil and become nontoxic to plants after several months.

Results of a survey of toxaphene residues on 1970 U.S. auction market tobacco were reported by Domanski and Sheets (1973). Approximately 26 percent of the flue-cured tobaccos contained toxaphene, but most values were below 1 ppm. Toxaphene was present in 4 of 22 burley samples, but these were at relatively low levels. Most air-cured and fire-cured samples contained toxaphene; a few concentrations were above 8 ppm. One dark aircured tobacco sample contained 12 ppm.

In a similar study of tobacco products in 1971, Domanski, et al., (1973) found that toxaphene was present in all products except regular cigars. Toxaphene residues in cigarettes averaged 3.3 ppm, in chewing tobacco 1.4, in snuff - 1.2, in cigars - 0.6, little cigars - 0.6, and in pipe tobacco 1.6 ppm.

III.H. Fate in Soil

The long time use of persistent pesticides such as toxaphene and their resulting ubiquitous occurrence has prompted much public concern about the effects of such compounds on the environment.

Pilot studues were conducted nationwide at 51 locations over three years (1965-67) to determine existing pesticide residue levels in soils. Samples were taken from areas regularly treated, infrequently treated, and in locations with no known previous use of insecticides. Soils from areas where cotton and vegetables are grown contained 0.66-9.38 ppm toxaphene/Strobane in 60 percent of the fields. Only one orchard (3 percent of total sampled) contained toxaphene residues (7.72 ppm). Soils from twelve percent of all small grain-root crop areas contained toxaphene in amounts from 0.11 to 2.01 ppm. Toxaphene residues were not detected in limited or no use areas (Stevens, et al., 1970).

A follow-up survey was conducted by Wiersma, et al., (1972). Pesticide residues in cropland soil for 43 States and non-cropland soil for 11 States were measured. On cropland soil 4.2 percent of the sites sampled contained toxaphene residues within the range 0.10 to 11.72 ppm. Only one of 199 non-cropland samples contained toxaphene. The amount detected was 0.52 ppm.

From 1953 to 1957 annual applications of 20 lb./ac./yr. of toxaphene were worked into California Holtville sandy clay. A rank of decreasing persistence (persistency index: 1.00 = no degradation or other disappearance during the first year) over

an 11-year period placed toxaphene treatments at 0.18 which suggests a low persistence (Hermanson, et al., 1971).

Movement and distribution of toxaphene in a heavy clay soil was studied on three Blackland Prairie watersheds in Texas. Less than 22 percent of the toxaphene applied over a 10-year period was recovered in the top 5 feet of soil. Ninety to 95 percent of the toxaphene was found in the upper 12 inches. A higher percentage was recovered in a field receiving 10 lb./ac. of toxaphene than 2 fields receiving 18 and 22 lbs. The reason for this seeming contradiction remains unknown (Swoboda, et al., 1971). Thomas (1970), who made a progress report on the same study mentioned that profile studies from waterways were found to contain almost no toxaphene. A silt sample contained only 0.06 ppm toxaphene.

One hundred kg/ha of toxaphene was applied to Dunbar topsoil in the South Carolina Coastal Plain. Loss from topsoil and accumulation in underlying ground water was monitored for 1 year. Loss from topsoil appeared to occur in two stages. The second (major) stage was crudely linear on a log residue vs. log time plot. Half residence time in the topsoil was about 100 days. Toxaphene was found in the underlying ground water within 2 months after application to topsoil and persisted during the entire year (La Fleur, et al., 1973).

The residual effect of insecticides applied to meadow and pasture control of the European chafer was investigated by Shorey, et al., (1958). Loss of residues and effectiveness as measured by chafer control showed that Strobane at 5 and 10 lb./ac. and

toxaphene at 10 and 20 lb./ac. did not afford adequate control during the first or succeeding years.

Persistence of toxaphene in air dried soil samples was recorded by Westlake and San Antonio (1960). Levels of toxaphene as shown by plotted curve, decreased from 140 to about 85 ppm over a 6-year span.

The fate of organic pesticide residues in soil, as reported by Adams (1967), was recalculated in terms of half lives in soil with data taken from Foster, et al., (1956). The approximate half life of toxaphene in soil as 2.0 years for Beltville, Maryland, 0.8 for Mississippi, and 0.8 for New Jersey.

Distribution of chlorinated insecticides in cultivated soil (Congaree sandy loam) in Maryland was studied by Nash and Woolson (1968). Study plots were treated with a total of 73 or 146 kg/ha as frequently repeated foliar applications during the 1951, 1952 and 1953 growing seasons. Between 85 and 90 percent of the toxaphene residues were found in the upper 23 cm of the soil profile, which probably corresponded to the cultivated layer. Residual amounts remaining after 12 years (in 1964) were 51 percent of total application and 75 percent of 1954 assay. The amount of toxaphene remaining in the same soil type after 14 years was 45 percent of that applied. Treatments and maintenance of the soil were such that leaching, volatilization, photodecomposition, mechanical removal, and probably biological decomposition were at a minimum. This value probably approachs the upper limit of persistence in the soil (Nash and Woolson, 1967).

In 1969 the pesticide concentrations of 20 randomly selected Mississippi Delta Lakes were evaluated. The DDT complex and toxaphene were the prevalent pesticides found in bottom sediments. Toxaphene ranged from 0.0 - 2.47 ppm with half the lakes being negative for this chemical, but all lakes contained pesticides of some kind (Herring and Cotton, 1971).

Reimold and Durant (1972) made surveys of toxaphene levels in Georgia estuaries which received effluent material from a toxaphene manufacturing plant. An initial sample of ground wood particles and mud contained 4,200 - 4,700 ppm toxaphene when analyzed by three different laboratories. Similar samples taken about 2 months later at the same site and at the mouth of the stream contained 1566 ppm, and 310.7 ppm, and dredge spoil in the effluent area contained 30.6 - 32.8 ppm toxaphene. Concentrations in marsh surface sediment decreased with exposure to sunlight.

Monitoring of pesticides in agricultural soils of the Mississippi River delta was conducted by the Agricultural Research Service, USDA (1966). Determination of Strobane/toxaphene residues was attempted in 1964 on a few samples. In cultivated land, average levels ranged from 0.88 ppm to 3.78 ppm.

Soil samples collected from 33 cotton fields within the Flint Creek basin, Alabama, had no recent treatments so residues were

at least one year old. Toxaphene was present in 57.6 percent of the samples, with mean concentration of positive samples of 0.71 and a range of 0.16 to 1.6 ppm (Grzenda and Nicholson, 1965).

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Chapter IV

Toxaphene Residues in Crops and Food Items

IV.A. Introduction

Toxaphene is defined in Sec. 180.138 of the pesticide regulations as chlorinated camphene containing 67 percent - 69 percent chlorine.

A recent report (Casida, et al., 1974) involving the fractionation of toxaphene by thin-layer chromatography and column adsorption chromatography together with further resolution by combined gas-liquid chromatograph (GLC) - mass spectroscopy techniques reveals a complex mixture of at least 175 polychlorinated C_{10} compounds. The types of compounds include C_{10} H_{10} Cl_{10}, C_{10} H_{18-n} Cl_n and C_{10} H_{16-n} Cl_n where the chlorine number is 6,7,8 or 9. It is believed that the majority of the $C_{10}H_{16-n}Cl_n$ compounds are polychlorobornanes and that the $C_{10}H_{16-n}Cl_n$ compounds are polychlorobornenes and that the $C_{10}H_{16-n}Cl_n$ compounds are polychlorobornenes, polychlorotricyclenes or both. One toxic component is 2,2,5-endo, 6-exo,8,9,10-heptachlorobornane.

The FAO-WHO has assigned the "generic" name "camphechlor" to this insecticide and has developed specifications for the technical material (Dept. of State, 1972). These include an infrared absorptivity maximum at 7.2 um maximum acidity (based on percent by weight of HCl), a minimum softening point and a minimum specific gravity. The material produced by Hercules, Inc. over the past 20 years was relatively uniform and was the basis for these specifications. Available residue and toxicity studies were performed using such materials.

In the usual residue analysis, by GLC with an electron capture detector, toxaphene appears to contain about 30 components. These multiple peaks tend to interfere in the determination of other chlorinated hydrocarbon pesticides, such as DDT. Conversely, the presence of toxaphene may be obscured by interference due to other chlorinated hydrocarbon compounds in the substrate.

IV.B. Tolerances

U.S. Tolerances

The general level of 7-ppm for tolerances of toxaphene under Section 408 [3469] of the Federal Food, Drug and Cosmetic Act arose from the 1950 Spray Residue Hearings. The crops covered by the tolerances established at that time, and others at the 7-ppm level, are shown below. For convenience, in some cases, the crop groupings under Section 180.34(f) of the pesticide regulations (Part 180, Subchapter E, CFR) are indicated without naming the individual crops of the groups.

7ppm. Citrus fruits, corn, cucumbers, fruiting vegetables, the major leafy vegetables (broccoli, brussels sprouts, cabbage, cauliflower, celery, collards, kale, kohlrabi, lettuce, and spinach), nuts (hazel, hickory, pecans and walnuts), peanuts, the major pome fruits (apples, pears and quinces), several root crop vegetables (carrots, horseradish, the onion group, parsnips, radishes and or radish tops and rutabagas), the major seed and pod vegetables (beans - including dried beans; okra and peas), most of the small fruits (blackberries, boysenberries, cranberries, dewberries, loganberries, raspberries, strawberries and youngberries), and the major stone fruits (apricots, nectarines and peaches).

Only about 25 percent of the above tolerances were established via the petition routes. The remaining lower level tolerances for crops-all resulting from petitions-are:

5 ppm. The small grains (barley, oats, rice, rye, sorghum and wheat).

5 ppm. Cottonseed. (This tolerance is for chlorinated terpene of molecular weight 396.6 containing 67 percent chlorine). Expressed in this manner, the tolerance includes Strobane residues which are chemically indistinguishable from those of toxaphene).

3 ppm. Bananas (with no more than 0.3 ppm in the pulp) and pineapples.

2 ppm. Soybeans (dry form). This tolerance originally was established to cover a combined DDT - toxaphene use with a maximum combined residue of 3.5 ppm (1.5 ppm of DDT and 2 ppm of toxaphene).

There also are tolerances of 7 ppm for residues of toxaphene in the fat of meat from beef, goats, hogs, horses and sheep. These tolerances, which cover residues resulting from dermal applications to livestock, were established via the petition route.

Section 180.318 of the pesticide regulations established interim tolerances for toxaphene residues in or on alfalfa at 1 ppm and in milk at 0.05 ppm (equivalent to 1.25 ppm in the fat of milk).

In addition there are temporary tolerances of 7 ppm for residues in or on sugar beets and sunflower seeds. These tolerances were established in conjuction with experimental permits.

A food additive tolerance of 6 ppm for residues in crude soybean oil is "out-of-date". Such tolerances now are established only on refined oils.

Foreign Tolerances

The following tolerances were in effect as of May 1973.

Canada:

7 ppm. Fruits (citrus, pears and strawberries), meat, fat (cattle, goats, sheep and swine) and vegetables (beans, black-eyed peas, broccoli, brussels sprouts, cabbage, cauliflower, celery, eggplant, kohlrabi, lettuce, okra, onions, peas and tomatoes).

5 ppm. Barley, grain sorghum and rice.

3 ppm. Oats, pineapples, rye and wheat.

Germany:

0.4 ppm. Cherries, pears, plums, raspberries and strawberries.

The Netherlands:

0.4 ppm. Fruit and vegetables (except potatoes).

These tolerances are similar to those in effect in 1968 (Corneliussen, 1970).

Canada added the tolerance on rye and Germany apparently revoked a tolerance of 0.04 ppm on other plant products.

IV.C. Policy Considerations for Residues

Section 180.3 of the Pesticide Regulations deals with tolerances for related pesticide chemicals. Paragraph d(3) provides that where both Strobane and toxaphene are used on the same crop,

the combined residues shall not exceed the highest tolerance level for either pesticide (this applies only to cottonseed with a tolerance of 5 ppm. The regulation was written in anticipation of other tolerances being established for Strobane). Paragraph e of this Section includes toxaphene in the class of chlorinated organic pesticides. Where a crop bears residues of two or more pesticides in this class, there are additional limitations on the combined residues over and beyond the individual tolerance levels. The limitations vary with the availability of analytical methods for the individual pesticides and other regulations which permit exception (such as DDT and toxaphene on cottonseed where both pesticides may be present at their respective tolerance levels). In general, the percentage that residues comprise of the tolerance level, for each pesticide is calculated and the sum of the percentages may not exceed 100.

In 1969 the Chemistry Branch, Registration Division reviewed the established tolerances for toxaphene. The data of the 1950 Spray Residue Hearings were re-examined along with subsequent data from various sources. Considerations of the data and the use patterns led to the conclusion that the tolerances for the pome fruits could be reduced to 3 ppm and that tolerance of 2 ppm would be adequate for citrus fruits, cucumbers, grain crops, certain leafy vegetables, nuts, peanuts, seed and pod vegetables and small fruits. No further action was taken on the possible reduction of the established tolerances pending resolution of

the many inadequate feeding restrictions on toxaphene labels and in the absence of a poultry feeding study.

On May 5, 1972 (Pesticide News Letter, 1972), the Food and Drug Administration published the following "action levels" for toxaphene residues in commodities which are not covered by tolerances:

1 ppm

Fruits

Blueberries	Figs	Melons
Cherries	Grapes	Plums
Currants		

Vegetables

Artichokes	Potatoes	Sweet Potatoes
Asparagus	Pumpkins	Turnips
Beets	Squash	Turnip Greens or Tops
Mustard Greens	Summer Squash	Winter Squash

7 ppm

Poultry (fat)

IV.D. Acceptable Daily Intake

In 1968 the FAO-WHO reported that before an acceptable daily intake (ADI) or tolerance could be established, further information would be needed in the following:

1. Data on the uniformity of the technical product:
    a) variability in biological activity
    b) variability in chemical composition as determined by various analytical methods

c) variability in the raw material and final product from different sources

d) criteria for controlling the degree of chlorination

2. Information on the nature of residues in plants, animals and their products, including possible photo-oxidation products.

3. Additional data on crop residues from supervised trials.

4. Residue data for

a) poultry, cattle, sheep and swine

b) unprocessed and processed vegetable oils

c) cereals after processing into flour, bread, etc.

5. Development and comparative evaluation of regulatory, analytical methods.

6. Complete toxicological studies with a standardized technical product, the constituents of which have been identified.

At this time, the official report of the joint FAO/WHO meeting on pesticide residues in 1973 has not been issued. However, we have been advised-informally-by participants, that it was decided that an ADI cannot be established at this time. Although some of the deficiencies cited in the 1968 report have been resolved, and the FAO specifications for toxaphene have been met by one manufacturer (Hercules, Inc.), the available residue and toxicity data may not be pertinent to toxaphene from other sources. In addition, although there are no adverse data for toxaphene per se, there is a general question regarding the carcinogenic potential of chlorinated pesticides.

IV.E. Residues in Food

General Comments

Toxaphene shows little, if any, translocation in plants. Crop residues result from surface deposition and root crops would be expected to have only trace contaminative residues. The major mode of residue dissipation is volatilization. The available data on crops indicate a half-life on the order of 1-2 weeks. The GLC patterns obtained in chemical analyses show that crop residues consist primarily of unchanged toxaphene.

The persistence of residues in soil varies with conditions. High application rates and incorporation into the soil enhances persistence (Nash and Woolson, 1967). The major mode of dissipation, as in the case of crops, appears to be volatilization; residues show little tendency to leach (Swoboda, et al., 1971). However, some of the residues are probably degraded by soil micro-organisms (Paris and Lewis, 1973). The present use patterns for toxaphene, involving foliar applications to crops, do not present a problem of soil persistence from the viewpoint of residues in food. Residues in whole milk are about 1-2 percent of the level in cattle feeds. Levels in the fat of meat of cattle and other ruminants are about 1/2 of the level in the feed. The maximum residues in the fat of livestock from the registered dermal uses run about 4-5 ppm. The GLC patterns obtained in chemical analyses of fat show that the residues are primarily unchanged toxaphene. However, a report on milk (Li, et al., 1970), where only three of the toxaphene

peaks were found, indicates that the residue in milk may consist of an altered form of the pesticide.

The processing of food for canning or cooking, with such steps as washing, peeling, and heating typically remove 20-60 percent of toxaphene residues. The trimming of meat or cooking at high temperatures also will remove some residue. However, the processing of milk to dairy products such as cream, butter, buttermilk or cheese causes no reduction of residues on a butter fat basis (Li, et al., 1970).

Monitoring and Surveillance Data

The report on the EPA "National Soils Monitoring Program For Pesticide Residues - FY 1970" (Private Communication, A.B. Crockett, 1971) includes data for toxaphene residues on 4 crops in 35 States. On cotton (stalks and green bolls) residue values ranged from 0.7-56 ppm. Other residue values were well below tolerance levels viz: cottonseed 0.05-2 ppm; corn (stalks) 0.1 - 1.4 ppm; mixed hay 0.1 ppm (no tolerance here, but the level is quite low), and soybeans 0.1-0.4 ppm. There are no comparable data for the 1969 program, but the use patterns were similar. In 1969 1.9 percent of all sites were treated with an average of 11.1 kg of toxaphene per hectare. In 1970 2.45 percent of all sites were treated with an average of 10.7 kg of toxaphene per hectare. In both years use was concentrated in the cotton growing States with 14 percent or more of the sites being treated only in Alabama, Georgia, Mississippi and South Carolina.

An unexpected side-effect of the use of toxaphene on cotton is the presence of residues in commerically grown catfish (Paris and Lewis, 1973). A 1970 study of 50 catfish farms in Arkansas and Mississippi showed toxaphene residues of 0.2 to 21 ppm averaging 2.1 ppm in the edible portions of 96 percent of the 54 fish samples that were analysed. Seven percent of the samples had residue values in excess of the 5 ppm FDA action level. (FDA has informally advised that this would be the action level for fish). The average toxaphene level exceeded those for DDT, aldrin and dieldrin, endrin and mercury. A statistical analysis of the data indicated that cotton cropping was the primary source of contamination to the fish ponds. The routes of movement, however, could not be defined.

Between 1962 and 1970 the Food and Drug Administration conducted market-basket studies on pesticide residues in the food supply. Typically 30 composites each of 12 commodity groupings were analyzed for about 30 pesticides each year. No toxaphene was reported for the years prior to 1966. The data, where toxaphene was found (Duggan, 1977; Corneliussen, 1966, 1970, 1972), show that values of 0.1 ppm or higher were encountered infrequently, mostly in the Los Angeles District, and involved only 3 of the commodity groupings. The data for these groupings are tabulated below:

	Garden Fruits		Leafy Vegetables		Meat, Fish & Poultry	
Year	No. of Positive Composites	Range (ppm)	No. of Positive Composites	Range (ppm)	No. of Positive Composites	Range (ppm)
1966-7	-	-	1	0.39	-	-
1967-8	2	0.09-0.19	-	-	1	0.38
1968-9	6	0.03-0.23	3	trace-0.33	1	0.19
1969-70	2	0.13-0.15	-	-	-	-

A summary of the results of over 100,000 samples of raw agricultural commodities examined by FDA between 1963 and 1969 (Duggan, et al., 1971) shows toxaphene residues to occur relatively infrequently. The incidence of residues on 21 commodities (or groups of commodities) exceeded 2 percent only in the case of leaf and stem vegetables, vine and ear vegetables (for imported samples), cottonseed products (the highest at 29 percent), peanut products and soybean products. The average residues found were all $<$0.1 ppm except for leaf and stem vegetables at 0.2 ppm (1.2 ppm for imports), tree nuts at 0.2 ppm (1.6 ppm for imports), and refined cottonseed oil at 0.12 ppm. The report also includes data for over 12,000 domestic and almost 4,000 imported meat samples examined by the Consumer and Marketing Service, USDA. The incidence of residues was on the order of 1 percent and average residues were no more than 0.01 ppm. No residues were found in over 3,000 samples of poultry examined in 1968-69. The data for calendar year 1973 (private communication, W. A. Rader) show a similar pattern. However an examination of the individual values shows a number of samples with toxaphene residues on the order

of several ppm; but only one of 1355 samples of the meat (fat) of horses, cattle, calves, lambs and swine had a residue in excess of the tolerance of 7 ppm. Similarly for poultry only one of 1162 samples had a residue exceeding 7 ppm.

An examination of the submittals from the FDA Division of Regulatory Compliance under the Interdepartmental Agreement on Pesticides shows that during the period 1968-1973 the number of samples which included tolerance residues of toxaphene was minimal.

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CHAPTER V

ECONOMIC EVALUATION OF TOXAPHENE

Toxaphene was produced in an estimated amount of 55 million pounds in 1973. The four manufacturers were Hercules, Incorporated, Tenneco, Incorporated, Helena Chemical Company and Sonford Chemical Company. In 1974 these companies continue to produce this insecticide.

The use of toxaphene is widespread, for both crop and non-crop purposes. By far the largest use is on cotton, with livestock pest control ranking second. Other crop uses include soybeans, peanuts, vegetables - cabbage, carrots, celery, lettuce, onions, tomatoes, sweet corn, and so forth, and small grains.

Insecticide usage on cotton has always been large and toxaphene, since the ban of DDT, has become one of the major chemicals applied to cotton. It is used to control the boll weevil and bollworm primarily, but also for controlling such insects as beet armyworms, cabbage loopers, cutworms, plant bugs, cotton fleahoppers and thrips. Seldom applied in straight formulations, most cotton growers use toxaphene in combination with methyl parathion in a 2 pound active ingredient: 1 pound active ingredient ratio.

In 1973 it is estimated that slightly over 48 million pounds of toxaphene were used on cotton throughout the Cotton Belt. The Southeast used slightly less than 50 percent of this 22 million pounds, with the Delta states using approximately 20 million pounds. The remaining 6 million pounds were used by the states in the Southwest and West.

The cost of a season-long program of the toxaphene-methyl parathion formulation on cotton in the United States is estimated to be $99.5 million. A program employing methyl parathion alone - the favored alternative to the combination currently in wide usage - would cost approximately $117.6 million. The increase in cost is $18.1 million. University experiments on the efficacy of alternative insecticides indicate no significant difference in yield or quality arising when methyl parathion is used alone instead of in formulation with toxaphene.

The toxaphene-methyl parathion program cost represented 2.90 percent of the value of production plus support payments for all U. S. Upland cotton harvested in 1973. If the methyl parathion program were implemented (as it has been in some areas of the West) this percentage would increase by .53 to 3.43 percent. The estimates of this report would indicate that growers in some regions have definite economic justification for their expressed opposition to turning away from the present program.

On livestock, target pests of toxaphene include cattle lice, sarcoptic scabies, screwworm, ear tick, sheep tick, sheep scab, and others. Because of its broad spectrum control and general effectiveness, toxaphene is the most widely used of the insecticides on livestock in general. Beef cattle accounted for 76 percent of its use in 1971.

One reason for the large use of toxaphene on beef cattle is the Federal quarantine program for the eradication of sarcoptic scabies. In 1973, 2.9 million head of cattle were treated in this program, 95 percent dipped in toxaphene. In 1974 fewer cattle are expected to be treated since

outbreaks of these pests have been reduced. In Texas alone from 1971 to March, 1974, 3.5 million cattle have been treated at an estimated cost of $.10 per head. The cost to the ranchers, however, is estimated to be $10 per head. This figure includes trim loss at slaughter, labor, moving cost, and potential weight loss incurred in the drives to the dipping vats.

In the control of lice, many ranchers are moving toward the use of a systemic insecticide in place of the old standby, toxaphene. The systemic controls both sucking lice and cattle grub - a problem throughout our country - while toxaphene controls only the biting lice. The systemics are generally more expensive than toxaphene (delnav would cost $.20 per application per head) and less residual, but the estimated 25 percent weight loss resulting if sucking lice are uncontrolled makes this added expense worth it to many ranchers.

The minor uses of toxaphene include soybeans, peanuts, vegetables and small grains. On soybeans, carbaryl (sevin) is used quite extensively, also, despite its higher toxicity to honeybees and reported phytotoxicity to some varieties. Carbaryl approaches the broad spectrum of insect control by toxaphene on peanuts. Other chemicals may be used as substitutes on the peanut acreage - diazinon, methoxychlor, and malathion - but they are less residual and require more frequent applications to attain comparable control. Lannate (methomyl) is a general substitute for toxaphene on vegetables, while for certain specific pests various substitutes are available. For control of the pests of the small grains carbaryl is a recommended substitute, with ethyl and/or methyl parathion suggested as substitutes for certain specific insects.

Production and Use Patterns

Industry Description

Toxaphene was produced in the amount of approximately 55 million pounds by four producers in 1973, perhaps as much as 85 percent by Hercules. Table 5-1 lists these manufacturers and their plant locations. In 1974 these same companies continue to produce this insecticide.

Table 5-1
Manufacturers of Toxaphene and Plant Location, 1973

Manufacturer	Plant Location
Hercules, Inc.	Brunswick, Georgia
Helena Chemical Co.	Memphis, Tennessee
Sonford Chemical Co.	Houston, Texas
Tenneco Inc.	Fords, New Jersey

Hercules, Incorporated produces a diversified line of industrial chemical and related products derived from four main sources - cellulose, rosin and terpenes, nitrogen, and petroleum. In 1972 commercial sales provided 88.2 percent of the total net sales and operating revenues, while space and defense volume provided the remainder. The synthetic fibers industry contributed twelve percent to total commercial sales ($98.6 million).

Within the synthetics department of Hercules, insecticides make up a small portion of the total number of products produced. Besides toxaphene,

which is produced at their Brunswick, Georgia, plant, other insecticides produced by this department include thiophosphate, Delnav (more commonly known as dioxathion - a substitute for toxaphene's use against livestock pests), Torak (dialifor), Thanite, and diethyltoluamide.

Tenneco, Incorporated, is a natural gas pipeline operator with diversified interests in integrated oil and gas, chemical, packaging, manufacturing, shipbuilding, and land use businesses and holds related investments in the insurance and banking fields.

Of Tenneco's 1972 operating revenue - $3.3 billion - chemicals provided 9.5 percent or $277 million. The largest contributor to their operating revenues in that year was made by the machinery, equipment, and shipbuilding operations (37.8 percent or $1.2 billion).

Helena Chemical and Sonford Chemical together produced an estimated four million pounds of technical toxaphene in 1973. These companies market their toxaphene and many of its formulations through Vicksburg Chemical, in the case of Helena Chemical Company, and Bison or Riverside in the case of Sonford.

Formulators of toxaphene number over 150. These companies distribute toxaphene in forms, often in combinations with other pesticides, popular for usage on the crops and livestock in their areas. Forms commonly used in many areas are an emulsifiable concentrate and a dust. Toxaphene is most often combined with methyl parathion for use on crops (cotton in particular). On livestock it is used as a back-rub, spray, or dip.

Geographic Use Distribution

Domestic. Estimates of domestic utilization are available from USDA pesticide use data. For the years 1966 and 1971 Table 5-2 summarizes toxaphene's domestic disappearance. Among its crop uses, cotton far outshadows all others as a major user of this insecticide. Livestock usage comes next in importance, in terms of total poundage, with soybeans and peanuts ranking third and fourth. Estimates of production for 1972 indicate that about 76 million pounds were produced with 58 million being used domestically and 18 million being exported.[1] With the demise of DDT, toxaphene, by itself and in combination with other insecticides, is being used as a substitute which is perhaps part of the explanation for the jump in domestic use between 1971 and 1972. Regional usage of toxaphene is delineated in Table 5-3.

Foreign. Foreign usage of toxaphene follows the same pattern as the domestic usage - cotton and livestock are the principal uses, followed by the smaller uses on vegetables, small grains, peanuts and soybeans. Manufacturing plants of this insecticide are known to be located in Nicaraqua and Mexico, with Russia believed to have production facilities, also. Another facility is scheduled to be in production by 1976 in Brazil when Hercules do Brasil Productos Quimicas Ltda. (Hercules Inc. solely owned Brazilian subsidiary) completes construction of its plant with an

[1] "Production, Distribution, Use and Environmental Impact potential of Selected Pesticides" by Edward W. Lawless et. al., 1974.

Table 5-2
Toxaphene Use - Total Poundage and Acreage by Crop, 1966 and 1971

	1971		1966	
	Million Pounds A.I.	Million Acres	Million Pounds A.I.	Million Acres
Corn	.182	.140	.004	.020
Cotton	28.112	3.275	27.345	3.881
Wheat	.026	.025	.270	.155
Other Grains	.462	.387	.152	.092
Soybeans	1.524	.951	.976	.543
Tobacco	.206	.020	.150	.061
Peanuts	1.356	.472	.980	.237
Other Field Crops	.085	.061	.107	.056
Alfalfa	.018	.016	.101	.044
Other Hay and Pasture	.032	.023	.009	.008
Irish Potatoes	.142	.047	.124	.077
Other Vegetables	.628	.175	.684	.205
Citrus	.009	.002	-	-
Apples	-	-	-	-
Fruits and Nuts	.058	.007	.015	.004
Nursery, Greenhouse,....	.027	N.A.	.002	-
Total Crop [a/]	32.867	5.601	30.924	5.383
Livestock [b/]	4.575		3.670	
Other [c/]	.022		.011	
Total	37.464		34.605	

a/ Includes all crops, pasture, rangeland and land in summer fallow.

b/ Includes livestock buildings.

c/ Includes pesticides for all other noncrop and nonlivestock uses.

Source: Quantities of Pesticides Used by Farmers in 1966, 1971, USDA - ERS

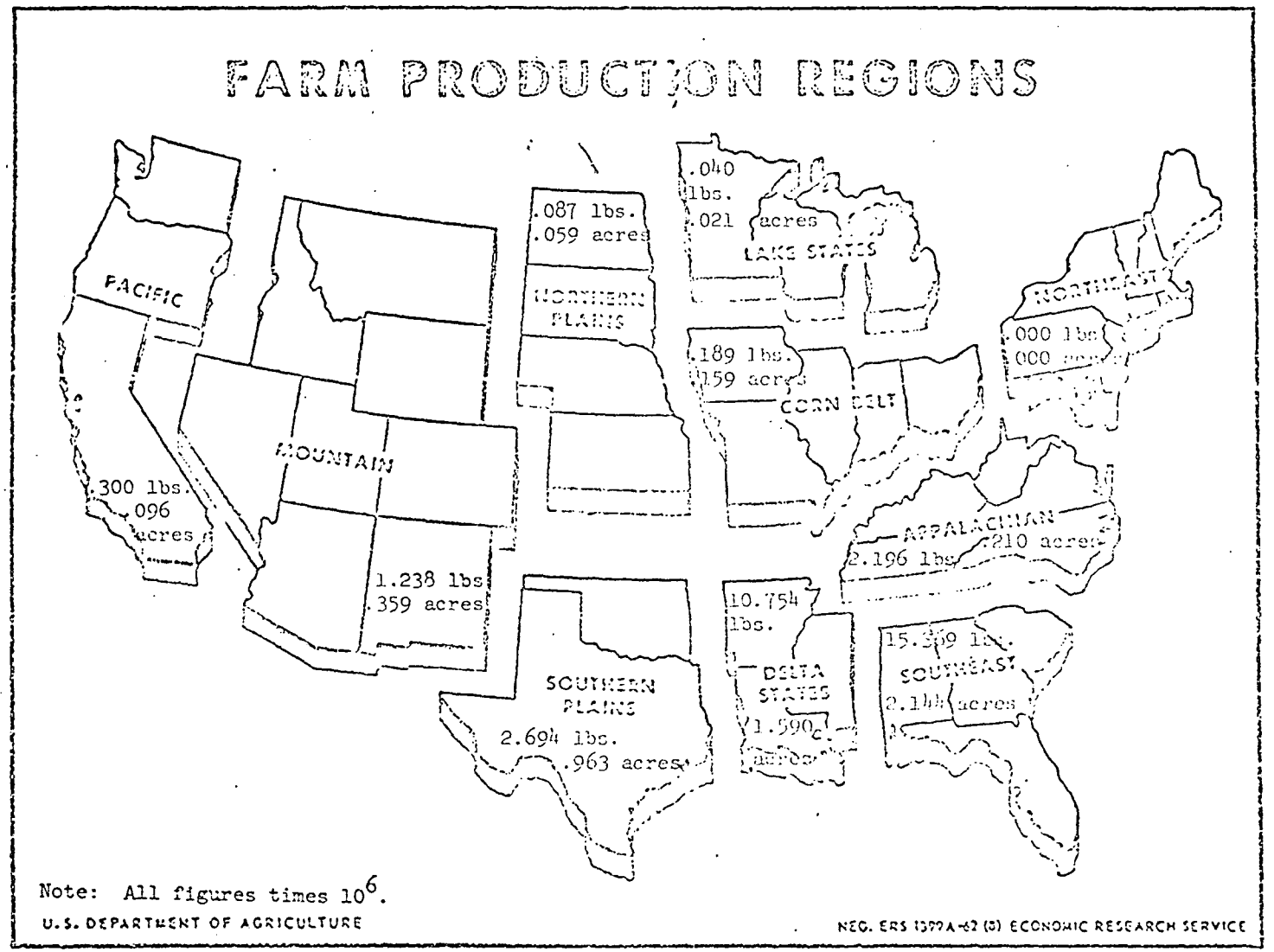
Table 5-3

Regional Patterns of Toxaphene Farm Use - 1964/1966/1971

Region	Millions of Pounds A.I.			Millions of Acres Treated		
	1971	1966	1964	1971	1966	1964
Northeast	-	.004	.003	-	.002	.020
Lake States	.040	.111	.050	.021	.013	.050
Corn Belt	.189	.403	1.300	.159	.307	.900
Northern Plains	.087	.007	.001	.059	.008	.002
Appalachia	2.196	2.521	4.200	.210	.544	1.100
Southeast	15.369	13.740	11.500	2.144	1.533	1.800
Delta States	10.754	7.176	10.300	1.592	1.233	2.200
Southern Plains	2.694	4.982	5.100	.963	1.304	1.400
Mountain	1.238	1.420	1.000	.359	.217	.200
Pacific	.300	.560	.800	.096	.202	.200
Total	32.867	30.924	34.200	5.601	5.383	8.000

Source: Quantities of Pesticides Used by Farmers in 1964, 1966, 1971, USDA - ERS

Figure 5-1
Regional Patterns of Toxaphene Farm Use, 1971



expected annual capacity of 25 million pounds. The United States itself is known to export toxaphene, which contributes to the supply available for foreign use. In 1972 exports were estimated to be 18 million pounds a.i.[1]

The United States appears to be playing the role of trend-setter in the use of pesticides in addition to its many other trend-setting activities. Thus, any restriction on domestic usage of a pesticide brings about repercussions in the world market for that pesticide, eliminating much of the use of the pesticide overseas. Restriction is not the only influencing factor in foreign markets. The establishment of tolerance levels in meat residues plus the pre-slaughter intervals required domestically are known in foreign countries and influence practices concerning the use of a particular pesticide such as toxaphene with its 7 ppm tolerance level and 28 day pre-slaughter interval.

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[1] "Production, Distribution, Use, and Environmental Impact Potential of Selected Pesticides", Lawless et. al., 1974.

Toxaphene Use on Cotton

In 1973 about 12 million acres of cotton were harvested in the United States. Production amounted to approximately 13 million bales with a value of almost $2.8 billion. The states of Arkansas, California, Mississippi, and Texas accounted for slightly over 70 percent of this production. When support payments were added to the value of production, the figure for U. S. Upland cotton alone increased from $2.7 billion (value without support payments) to $3.4 billion.[1]

Insecticide usage on cotton has always been large. Almost half of all the insecticides used by farmers on crops has been on cotton. Among these insecticides, toxaphene has been one of the most extensively used - prior to 1973, in formulations with DDT and others and after DDT's ban, in formulations with methyl parathion. Toxaphene's use on cotton, in fact, far outshadows its other uses, crop and noncrop. In 1971, 28.1 million pounds active ingredient - 85 percent of its total crop usage that year - were used on 3.3 million acres for an average of 8.6 pounds a.i. per acre, up from the 1966 average of 7.0 pounds a.i. per acre.

As a cotton insecticide, toxaphene is aimed at controlling such insects as beet armyworms, boll weevils, bollworms, cabbage loopers, cutworms, plant bugs, cotton fleahoppers, and thrips. When the figures concerning annual loss due to these pests are perused the large usage of insecticides on cotton is more easily understood. The estimated

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[1] Data on support payments for American-Pima for 1973 were not available at the time of this report.

Table 5-4

Cotton: Acreage, Planted and Harvested, Production, and Yield Per Acre on Harvested Acreage, By Regions, 1973

Region	Planted Acreage		Harvested Acreage		Production		Yield/Acre On Harveste Acreage
	1,000 Acres	% of Total	1,000 Acres	% of Total	1,000 Bales	% of Total	Pounds
West (a)	1,412	11.3	1,397	11.7	2,550	19.7	876
Southwest (b)	5,979	47.8	5,746	47.9	5,106	39.4	427
Delta (c)	3,672	29.4	3,480	29.0	3,985	30.7	550
Southeast (d)	1,439	11.5	1,366	11.4	1,320	10.2	464
Total	12,502	100.0	11,989	100.0	12,961	100.0	519

(a) California, Arizona, New Mexico, and Nevada

(b) Texas and Oklahoma

(c) Missouri, Arkansas, Tennessee, Mississippi, Louisiana, Illinois, and Kentucky

(d) Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama

Source: Cotton Situation, February, 1974, ERS-USDA

average annual loss in the period 1951 to 1960 was in excess of $476 million. The loss of cotton growers to the boll weevil alone has been estimated to be about $200 million annually and the suppression treatments cost an additional $75 million. More recent estimates show average losses to cotton insects amount to over $24.00 an acre with insect suppression costing more than $13.00 per acre.[1] The average annual loss, in percentage terms, that maybe attributed to various cotton pests is shown in Table 5-5.

Table 5-5

Average Annual Loss Attributable to Specified Cotton Pests

Insect	Average Annual Loss(%)
Boll Weevil	8.0
Bollworms	4.0
Lygus Bugs, Cotton Fleahopper, & Other Sucking Insects	3.4
Thrips, Spider Mites, Cotton Aphid, Cabbage Looper, Cotton Leaf Perforator, Pink Bollworm, Beet Armyworm, Cotton Leafworm, and other Insects	3.6
Total	19.0

Source: National Cotton Council of America

As would be expected, the regional use pattern of toxaphene is literally dictated by its use on cotton. Over three-fourths of its total poundage used on crops in 1971, 26 million pounds, was used in the

[1] National Cotton Council of America.

Southeast and Delta states of Arkansas, Mississippi, Louisiana, Alabama, Georgia, South Carolina and Florida. (For a more detailed regional breakdown, see Table 5-5 above.)

Chemical Alternatives

Methyl parathion ranks high on the list of substitutes for toxaphene's usage on cotton. In most areas it is a highly effective compound against the boll weevil and members of the bollworm complex as a contract spray at rates of one to two pounds per acre.

This insecticide was produced by four manufacturers throughout the United States in 1972. Production was reported to be slightly in excess of 51 million pounds with four plants producing and a fifth available. Total annual capacity of these five plants is in excess of 100 million pounds.[1] In 1973 there were reported to be, once again, four producers, but one company had been replaced by another and annual capacity had increased slightly to an estimated 106 million pounds.[2] It seems that even if the extreme assumption is made that all the toxaphene usage on cotton is replaced by methyl parathion and the accompanying increase in the number of applications is accounted for (necessitated by the decrease in the period of effectiveness of methyl parathion), existing facilities do have the capacity to handle the switch in usage.

There are some disadvantages to using methyl parathion as opposed to toxaphene. As mentioned above, its residual effectiveness is shorter, requiring more applications during a growing season. During a ten-week

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[1] "Production, Distribution, Use and Environmental Impact Potential of of Selected Pesticides," MRI Report.

[2] 1973 Directory of Chemical Producers, USA, CIS, SRI

period, 23 applications of methyl parathion would be required (at 3-day intervals) as opposed to toxaphene's 14 applications (5-day intervals).[1] An important factor in areas with short growing seasons would be the delay in maturity in most varieties of cotton. It apparently acts as a stimulus to cause excessive vegetative growth in itself, and if soil moisture and fertility are high the plants will respond by growing taller and delaying maturity.[2] Methyl parathion is highly toxic and all presently registered formulations (except a dry formulation of less than two percent a.i. content) present serious hazards to operators and persons entering treated areas soon after application without adequate protection. It is also highly toxic to honeybees and to other beneficial insects.

Other insecticides that might substitute for toxaphene on cotton acreage include azodrin and carbaryl (sevin). Azodrin has been shown to be only marginal in effectiveness on cotton pests. Its high toxicity to birds is another factor causing disfavor to be shown for use of this insecticide. Carbaryl by itself is not highly effective and molasses is often added to it to increase its effectiveness. This mixture, too, has generally little success where insect infestation levels are high.

Insecticides registered in the not-too-distant past and showing promise for bollworm control include fundal, galecron, and phosvel (experimental label only). Lannate shows some promise, but is not

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[1] Generally accepted period of effectiveness for toxaphene applications is 5 to 7 days and for methyl parathion 3 to 5 days.

[2] Weaver, J.B., Jr. and Lawrence H. Harvey, "A Comparison of Toxaphene and DDT with Methyl Parathion on 49 Varieties and Strains of Cotton".

fully registered for use on cotton. Pencap M, a formulation of microcapsules containing methyl parathion dispersed in water, has recently been given an experimental label for use on cotton. It has several advantages over the usual formulation of methyl parathion as an emulsifiable concentrate: (a) lower toxicity, both orally and dermally; (b) longer effective control range - 5 to 7 days as opposed to the 3 day effectiveness of methyl parathion in its more usual form; and (c) field data show it is more efficacious, also, with yields of 1457 pounds of seed cotton per acre as opposed to a yield of 1307 pounds when methyl parathion was applied as an emulsifiable concentrate.

Non-Chemical Alternatives

(1) Releases of green lacewing and certain parasitic wasps to control the bollworm and pink bollworm are being made. Additional research on mass production, timing, release methods, and other operative techniques needs to be completed before the potential effectiveness of this method can be fully determined.

(2) A bacterium (Bacillus thuringiensis) has been registered for use on cotton and a Heliothis virus has been given an experimental label. Additional research is required to improve production methods, reduce costs, and provide consistent results before insect diseases will be practical tools for cotton producers.

(3) A new genus of the nematode Merithidae (anthonomus grandis) has been found that parasitizes the boll weevil. This nematode causes the weevil to emerge from hibernation abnormally early - four to six weeks before the cotton is even planted - and finding no cotton plants to feed on, it dies,

Table 5-6

Toxaphene Used on Cotton, Total Cost (Material and Application) of Current Toxaphene-Methyl Parathion Treatment, and Total Cost of Proposed Methyl Parathion Program, by Regions, 1973

Region[1/]	Toxaphene on Cotton (1,000 pounds)	Total Cost	
		Toxaphene-Methyl Parathion[2/] ($1,000)	Methyl Parathion[3/] ($1,000)
West	3,627	6,851	6,029
Southwest	2,690	5,034	5,625
Delta	19,746	47,075	60,732
Southeast	22,090	40,570	45,231
Total	48,153	99,530	117,617

1/ As designated in Table 5-4.

2/ Calculations of total cost for toxaphene-methyl parathion treatment based on a $2.70 material cost per acre-application plus a $1.00 application cost per acre-application; the formulation used is 2 pounds a.i. toxaphene and 1 pound a.i. methyl parathion.

3/ Calculations of total cost of proposed methyl parathion program are based on a $1.75 material cost per acre-application plus a $1.00 application cost per acre-application; the formulation assumed is 1 pound a.i.; and applications increase by 50 percent due to the shorter residual quality of methyl parathion (except in certain areas of the West - see text); the mix of cotton acreage treated with other insecticides remains constant when shift to the methyl parathion program is made; and total production does not change when toxaphene-methyl parathion is no longer used (the increase in the number of applications when methyl parathion is used is considered to give comparable insect control).

Note: Table based on estimates of Acreage and application rates as received in personal communications with entomologists in the regions. See list of entomologists contacted at end of chapter.

releasing the female nematodes in the soil to infest later generations of weevils. Continued research is in progress and when the life cycle of this nematode is known it may be possible to mass produce this parasite as a natural method to aid in control of the boll weevil.

(4) Cotton varieties resistant to insect attack are not currently available.

(5) The sterile male technique cannot presently be utilized to control cotton pests.

(6) Promising leads into insect hormones and pheromones to control or manipulate insect pests exist but further research is necessary.

Integrated Pest Management Programs in Cotton

Integrated pest management programs were begun in 14 cotton-producing states in 1972.[1] Ideally, these programs follow an approach which maximizes natural controls of pest populations. An analysis of potential pests is made, and based upon knowledge of each pest in its environment and its natural enemies, farming practices are modified (such as changes in planting and harvesting schedules) to affect the potential pests adversely and to aid natural enemies of pests. Once these preventive measures are taken, the fields are monitored to determine the levels of pests, their natural enemies, and important environmental factors. Only when the threshold level at which significant crop damage from the pest is likely to be exceeded should suppressive measures be taken.

[1] Some states had begun programs before this time.

Initially set down as three-year projects, funding from USDA is distributed on a formula based on cotton acreage in each state. Additional funds are provided by the Cooperative Extension Services and there is significant but lesser direct regulatory and research support of programs. Besides being economically practical for the grower, these projects must supply insect control as good or better than that provided by customary practices. Yield and quality cannot be reduced and new or improved control practices must be compatible with other pest control and agronomic practices, and with local environmental conditions. New environmental and pesticide regulations must be met.

In actuality, the primary emphasis of these projects to date, has been placed on the applications of insecticides based on economic thresholds of insect-pests. This will hopefully limit the practice of insecticide application by the calendar and bring about a schedule based on economic need.

With the demise of DDT and the wariness with which all the other organochlorines (including toxaphene) are now being viewed, there is an emphasis in research to find some substitutes among the organophosphates for cotton insect control. This switch has changed the economics of pest control. Besides being less residual, these insecticides are generally more disruptive to the beneficial insect complex.

These factors emphasized the need for a reevaluation of pest control. All too often the objective has been to kill insects rather than to prevent economic loss. Entomologists and growers alike have often lost sight of this objective in their zeal to maintain a "clean field". The killing of insects

below a sub-economic level for the sake of having a "clean field" is a luxury that can no longer be afforded. Research in California seems to bear this out.

> One prominent characteristic of recent bollworm control research that has stood out has been the consistent lack of correlation between worm reduction and yield. In many cases the most effective treatments from the standpoint of worm population reduction have resulted in our lowest yields. Often the untreated checks have harvested more lint per acre than the seemingly effective treatments. 1

In Texas, the growers have begun to delay the initial treatments of their cotton acreage until early July realizing that throughout June there are enough predators present in the fields to control the heliothis problem. Results of a three year study of a pest management program in the Pecos area demonstrate the economic benefits in terms of reduced costs resulting from the program as opposed to a season-long preventive program.[2] Yields of the acreage in the management programs did not significantly differ from the yields of the acreage treated in the conventional manner.

Unfortunately, there are very little data on the actual types of insecticides used in these management programs. USDA-ERS is at present beginning to monitor the growers in the programs for more detailed information on all types of pesticides employed. Robert van den Bosch, noted for his work in pest management, has stated that

> "to best fit the integrated control purpose, insecticides should have certain attributes in addition to killing capacity. These are (i) relative selectivity, (ii) limited residuality and (iii) manageability. The residual organochlorines do not fit this formula,

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[1] J. Hodge Black in Kern Cotton, March 5, 1971.

[2] T. L. Pate, et al, A Management Program to Reduce Cost of Cotton Insect Control in the Pecos Area, Texas A&M University, Texas Agricultural Experiment Station, February, 1972.

and because of this they have virtually no place in the integrated control scheme. These materials are, in fact, 'lazy man's' insecticides, programmed by their very characteristics of broad spectrum toxicity, long-lasting effect, and low cost, to do the impossible - provide unilateral pest control... Under integrated control the crops and their associated insect populations are monitored, and decisions to use insecticides are based on information derived from these monitorings. In this way insecticide usage is pinpointed as to when and where it is necessary. Furthermore, knowledge of crop development and pest behavior, biology and seasonal activity permits flexibility in the kinds of materials that may be used." [1]

As the concepts of integrated control become more widespread, there should be definite changes in the types of chemicals used and the timing of their applications. Also, the percentage of total variable cost of cotton production contributed by pesticides (estimated at 15 percent in 1972)[2] should decrease. As the details of these programs become available it shall be interesting to see if these changes come about.

Alternative Production Costs

The insect problem in cotton varies with the region in question. In the Southeast and Southwest the major pests are the bollworm and the boll weevil. In these areas, also, the tobacco budworm occassionally reaches levels of high infestation and becomes important from an economic standpoint. Moving further west, the pink bollworm becomes the major pest of Arizona's cotton acreage while lygus bugs are the dominant problem in California.

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[1] van den Bosch, Robert, "Statement on Aldrin-Dieldrin."

[2] Figures obtained from Irving R. Starbird, ERS, USDA, Fibers Section.

Pesticide usage varies due to the diversity of major pests in the cotton producing states. In general, the same chemicals or combinations are available in all areas, but practices with regard to the use of these chemicals change from one end of the Cotton Belt to the other.

In 1972, fifteen percent of the total variable cost per harvested acre of cotton production was accounted for by insecticides, herbicides, defoliants, and other chemicals.[1] Insecticides alone accounted for 7 percent of the total variable cost. Since then, despite the increasing costs of all inputs in cotton production - many production items have exhibited a 26 percent increase in price with fertilizer and motor supplies increasing by 52 percent since 1972 - insecticides have maintained their percentage share of the total.[2]

Specific insecticides have been widely used on cotton over the years. Prior to its cancellation, DDT was prodigiously applied to cotton acreage, quite often in formulations with toxaphene or toxaphene-methyl parathion. With the demise of DDT, the mixture of toxaphene-methyl parathion has taken over the number one spot, in terms of amounts used, in the ranking of insecticides used on cotton. Today, this combination is well promoted by formulators throughout the Cotton Belt, resulting in an extensive amount of toxaphene being used on cotton. Table 5-6 presents the estimated total poundage used on cotton by areas of the United States.

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[1] Other chemicals include flame cultivation oil, spreaders, stickers, mulsifying agents, and seed treatment chemicals.

[2] Sterbird, Irving R. "Costs of Producing Upland Cotton in 1972", Cotton Situation, April, 1974, USDA-ERS.

Table 5-6 also presents the estimated costs of the use of the toxaphene-methyl parathion combination (straight toxaphene is rarely used on cotton) as based on the following assumptions:

(a) all acreage (as estimated by entomologists in the areas delineated) is treated with toxaphene-methyl parathion in a 2 pound active ingredient + 1 pound active ingredient formulation per acre;

and (b) the total cost per acre per application is $3.70 (material cost per acre is $2.70 plus a $1.00 per acre fee for application).

The cost of a season-long program using the alternative most widely suggested for use, methyl parathion, was also estimated and presented in Table 5-6. The assumptions for this are as follows:

(a) all acreage is treated with methyl parathion in a 1 pound active ingredient formulation;

(b) the number of applications increases by 50 percent due to the shorter residual quality of methyl parathion (except in Arizona, New Mexico, and Nevada where it is indicated that equal numbers of applications provided equivalent control);

(c) total cost per acre per application is $2.75 (material cost per acre is $1.75 and the fee for application is $1.00 per acre);

(d) the mix of cotton acreage treated with other insecticides remains constant when the shift to the methyl parathion program is made;

and (e) total production does not change when toxaphene-methyl parathion is no longer used; the increase in the number of applications necessitated when methyl parathion is used is considered to give comparable insect control.

In the northern-most growing areas the use of methyl parathion, especially when begun early in the season and continued throughout, results in delayed maturity of the plant and causes some loss to the growers - estimated at

25 to 30% every four years.[1] The tobacco budworm is resistant to the organophosphates in areas of the Southeast and Southwest and when infestation levels are high the use of methyl parathion in combination with another chemical (toxaphene, endrin, EPN,...) is necessitated for effective control. (Tests showed no significant difference in yield on acreage receiving 12 applications of methyl parathion and the check plots when infestation of the tobacco budworm was high.)[2] This implies a higher cost outlay and would increase the season-long treatment costs in these areas.

Results of field tests in various areas of the Cotton Belt indicate that there is no significant yield or quality difference arising from the use of methyl parathion alone as opposed to the toxaphene-methyl parathion mixture. See Table 5-7. Appendix tables present the results of other efficacy tests of insecticides on cotton. (Present research is concentrating on insecticides of families other than the organochlorines and other formulations than the typical EC - emulsifiable concentrate.)[3]

Cotton production costs would increase by slightly over $18 million in the United States if a program using methyl parathion alone were implemented. In terms of the proportion of value of production (plus support),

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[1] Personal communication with Dr. R. L. Robertson, Department of Entomology, North Carolina State University.

[2] Personal communication with Dr. D. F. Clower, cotton research entomologist, Louisiana State University.

[3] Current research in Texas indicates that insecticide use on cotton may have gone full-circle back to dust formulations. See Hanna, R. L., "A Quarter Century of Cotton Insects in the Brazos Valley," unpublished manuscript.

Table 5-7

Effectiveness of Several Insecticides Against Boll Weevil, Bollworm, and Tobacco Budworm on Cotton, Waco, Texas, 1968 1/

Insecticide and dose (Pounds/Acre)	Percent boll weevil-punctured squares	Percent injured by Heliothis spp.		Yield (pound seed cotton per acre)
		Squares	Bolls	
	(6 LV Applications), July 17 - August 9			
Methyl parathion (0.75)	15.6 a	10.2 b	13.8 b	967 a
Methyl parathion (0.75) + DDT (1.0)	15.1 a	9.4 bc	8.1 c	961 a
Toxaphene (2.0) + methyl parathion (0.75)	14.0 a	10.3 b	10.5 c	942 a
Toxaphene (2.0) + DDT (1.0)	17.9 a	8.2 c	10.0 c	916 a
Toxaphene (2.0) + DDT (1.0) + methyl parathion (0.75)	15.0 a	9.1 bc	8.9 c	1018 a
Check	21.8 a	16.5 a	20.2 a	556 b

1 Means followed by the same letter are not significantly different at the 5-percent level of confidence by Duncan's multiple range test.

Source: "Field Evaluation of Insecticides for Control of the Boll Weevil, Bollworm and Tobacco Budworm on Cotton, Waco Area, Central Texas, 1968," C.B. Cowan and J.W. Davis, in Investigations of Chemicals for Control of Cotton Insects in Texas, 1968, Texas A&M University, Texas Agricultural Experiment Station.

Table 5-8 illustrates the .53 percent increase that results - the toxaphene-methyl parathion program represents 2.90 percent of the 1973 value of production while the program using methyl parathion by itself represents 3.43 percent. Once again, regional differences exist and these figures indicate that growers in the Delta and Southeast have economic justification for their opposition to turning away from the present program (utilizing the toxaphene-methyl parathion formulation) than growers in the West (where many have voluntarily made the switch already) and Southwest.

Table 5-8

Cotton: Value of Production Plus Support Payments Received by Growers and Calculated Insecticide Program 1/ Costs as a Percentage of this Amount, by Regions, 1973

Region 2/	Value of Production Plus Support Payments 3/ ($1,000)	Toxaphene-Methyl Parathion Program Cost as % of Value of Production Plus Support Payments	Methyl Parathion Program Cost as % of Value of Production Plus Support Payments
West	657,666	1.04	.92
Southwest	1,378,003	.37	.41
Delta	969,297	4.86	6.27
Southeast	428,743	9.46	10.55
Total (U.S. Upland)	3,433,709	2.90	3.43

1/ See Table 5-6.

2/ As designated in Table 5-4.

3/ Figures from Crop Values, January 1974, Crop Reporting Board, SRS, USDA.

Toxaphene Use on Livestock

In 1971, 4.6 million pounds of toxaphene were used on livestock, by far the largest share on beef cattle (76 percent). Some of the target pests at which toxaphene is aimed include cattle lice, sarcoptic scabies, screwworm, ear tick, sheep tick, sheep scab, and others. Toxaphene along with three other insecticides (dichlorvos, methoxychlor, and carbaryl) were the leaders for treating livestock in 1971.

In 1965 annual losses caused by livestock pests to all types of livestock were estimated to be $500 million.[1] Prior to the USDA state cooperative programs the annual loss to the cattle industry from scabies mite was $48.8 million. The loss to the sheep industry if sheep scabies were not controlled was $13.6 million.

Although there are many insecticides used on livestock, toxaphene is the most widely-used because it is highly effective and controls a broad spectrum of livestock pests, thus requiring a minimum number of applications for effective control. The uses of toxaphene and its major substitutes by type of livestock for the years 1966 and 1971 are summarized in Table 5-9.

For livestock dipping and spraying of toxaphene, as well as to provide for its possible entry into the animal diet, a tolerance of 7 ppm. in meat fat has been established. Regular examination of tissues from meat animals and poultry slaughtered in federally inspected plants

[1] "Losses in Agriculture Handbook No. 291," Agricultural Research Service, USDA, August, 1965.

TABLE 5-9

Quantities of Selected Insecticides (Toxaphene and Its Major Substitutes) Used on Livestock, by Type of Livestock, United States, 1966 and 1971

Insecticide	Dairy Cattle		Beef Cattle		Hogs		Poultry		Sheep		Other		Total	
	1966 (1,000 lbs.)	1971 (1,000 lbs.)	1966 (1,000 lbs.)	1971 (1,000 lbs.)	1966 (1,000 lbs.)	1971 (1,000 lbs.)	1966 (1,000 lbs.)	1971 (1,000 lbs.)	1966 (1,000 lbs.)	1971 (1,000 lbs.)	1966 (1,000 lbs.)	1971 (1,000 lbs.)	1966 (1,000 lbs.)	1971 (1,000 lbs.)
Toxaphene	138	200	3,180	3,483	266	843	22	4	51	39	13	6	3,670	4,575
Lindane	24	14	130	226	124	164	5	5	6	4	4	3	293	416
Methoxychlor	883	872	597	1,011	14	58	4	9	5	18	6	20	1,509	1,988
Ruelene	1	2	128	215	-	*	-	-	-	-	-	-	129	217
Coumaphos	1	18	423	147	1	2	9	*	-	1	-	*	434	168
Ronnel	36	33	294	384	34	44	24	7	2	1	1	1	391	470
Malathion	196	142	334	357	65	88	121	38	2	3	17	24	735	652
Dichlorvos	846	2,109	43	153	15	26	2	75	-	2	1	33	907	2,398
Carbaryl	1	18	135	196	1	52	407	928	-	*	4	*	548	1,194
DDT	29	55	447	158	16	27	8	*	2	3	3	2	505	245

*Less than 500 pounds.
Source: Quantities of Pesticides Used by Farmers in 1966, 1971, USDA-ERS.

are allowed for in USDA Consumer Protection Programs. Tabulations were made of animals inspected in 1969 and the first half of 1970 showing detectable residues of some chlorinated pesticides in 90 percent of the samples. In 1969 toxaphene was found in only 2 of the 3,169 meat samples and 2 of the 2,199 poultry samples. In the first six months of 1970, 3 of the 1,871 meat samples and none of 1,486 poultry samples contained toxaphene.

In the same samples for 1969 and early 1970, some of toxaphene's substitutes that were found as residues in the samples with low frequency included chlordane (2) and methoxychlor (74). Others appearing with somewhat greater frequency included lindane (505) and heptachlor (752). Although residues were found in all of these, it should be noted that the levels of these residues did not exceed .50 ppm. (fat basis).

The Nation's farmers and ranchers had 127.5 million cattle and calves in their herds on January 1, 1974, up 5 percent from a year earlier. Sheep and lamb numbers declined 7 percent and chicken numbered around two percent less than a year ago. Hogs and pigs increased in number by 3 percent.

This inventory of cattle and calves is the highest on record and is the seventh consecutive year of increase. The number of beef cows increased 5 percent but the number of dairy cattle declined 3 percent. The value of cattle and calves on farms and ranches amounted to $40.9 billion, an increase of 34 percent over a year ago. The average value per head increased from $252 on January 1, 1973, to $321 on January 1, 1974. Milk cows produced nearly 4 percent less milk in 1973 than during the previous year.

The average value per head of all sheep and lamb increased from $26.40 on January 1, 1973 to $32.70 per head on January 1, 1974, resulting in a total value of $540.7 million. The average value per head of hogs was $60.40 compared to $42.00 a year earlier. Total value of all hogs and pigs on hand was $3.7 billion, an increase of 48 percent over the previous year.

Alternative Production Costs

Toxaphene's largest use on beef cattle is in the Federal quarantine program to control scabies. In the list of permitted pesticides, there are two insecticides recommended for control of this disease - toxaphene and heated lime sulphur. A year ago 2.9 million head of beef cattle were treated, with 95 percent being dipped in toxaphene. Since then, outbreaks of cattle pests have been reduced so that the number of cattle to be dipped is expected to decrease from the 1973 figure.

About 750,000 cattle were dipped in toxaphene along the Mexican border in an effort to control for scabies and ticks. The present border protection program allows for dipping in Mexico prior to entry into the United States. The balance of the cattle dipped were in the Central and Southwestern states. Precautionary dipping is practiced in the Western States due to the existing fear that an outbreak of scabies may occur at any time. Since this is not really "official" dipping it is not necessarily included in the listings of cattle dipped.

TABLE 5-10

Leading Livestock States
Number on Farms and Ranches, January 1, 1974

All Cattle and Calves		Beef Cows that have Calved		Cattle on Feed		Sheep and Lamb		Pig Crop - 1973	
State	1,000 Head	State	1,000 Head	State	1,000 Head	State	1,000 Head	State	1,000 Head
Texas	16,250	Texas	6,470	Texas	2,205	Texas	3,200	Iowa	19,062
Iowa	7,660	Missouri	2,594	Iowa	1,715	Wyoming	1,505	Illinois	11,228
Nebraska	7,410	Oklahoma	2,379	Nebraska	1,525	Colorado	1,150	Missouri	6,883
Kansas	6,990	Nebraska	2,248	California	1,204	California	1,122	Indiana	6,731
Missouri	6,200	South Dakota	2,058	Kansas	1,160	South Dakota	976	Minnesota	6,074
Oklahoma	6,020	Kansas	2,050	Colorado	930	Montana	794	Nebraska	4,896
California	5,250	Iowa	1,790	Arizona	609	Utah	782	Ohio	3,187
South Dakota	5,000	Montana	1,746	Illinois	530	New Mexico	708	South Dakota	3,132
Wisconsin	4,400	Mississippi	1,285	Minnesota	464	Idaho	665	Kansas	3,033
Minnesota	4,240	Florida	1,282	South Dakota	381	Ohio	582	North Carolina	2,946
Colorado	3,744	Kentucky	1,247	Oklahoma	292	Iowa	531	Wisconsin	2,226
Montana	3,380	North Dakota	1,178	Ohio	280	Arizona	497	Georgia	2,437

Source: South Dakota Agricultural Statistics, South Dakota Crop and Livestock Reporting Service, May, 1974.

As the only existing permitted alternative to toxaphene, heated lime sulphur is not entirely acceptable; its use requires much more care than does the use of toxaphene and it is much more expensive. Although it is not as effective on some of the scabies, it can be used on lactating animals and in this capacity it was used on 5 percent of the cattle dipped in 1973. To be effective, the sulphur must be heated to a range of 95° to 105° F. (suggested in U. S.), therefore making it less convenient to use. It is also very corrosive to equipment used in its application and extreme care must be taken in the cleaning of this equipment when applications are complete.

Present methods of toxaphene's use on mites are in concentrations high enough to kill all pests present at the time. This assures that no mites remain to develop a resistance to the insecticide. Even cattle that have been exposed to the scabies mite are treated as an extra assurance of the complete eradication of these pests. As far as ticks are concerned, resistance has posed no problem over the years. Animals presented at the border are to be free of ticks. Detection, however, is relatively hard in these circumstances, but tests run on Mexican ticks have indicated that they are not developing a resistance to toxaphene.

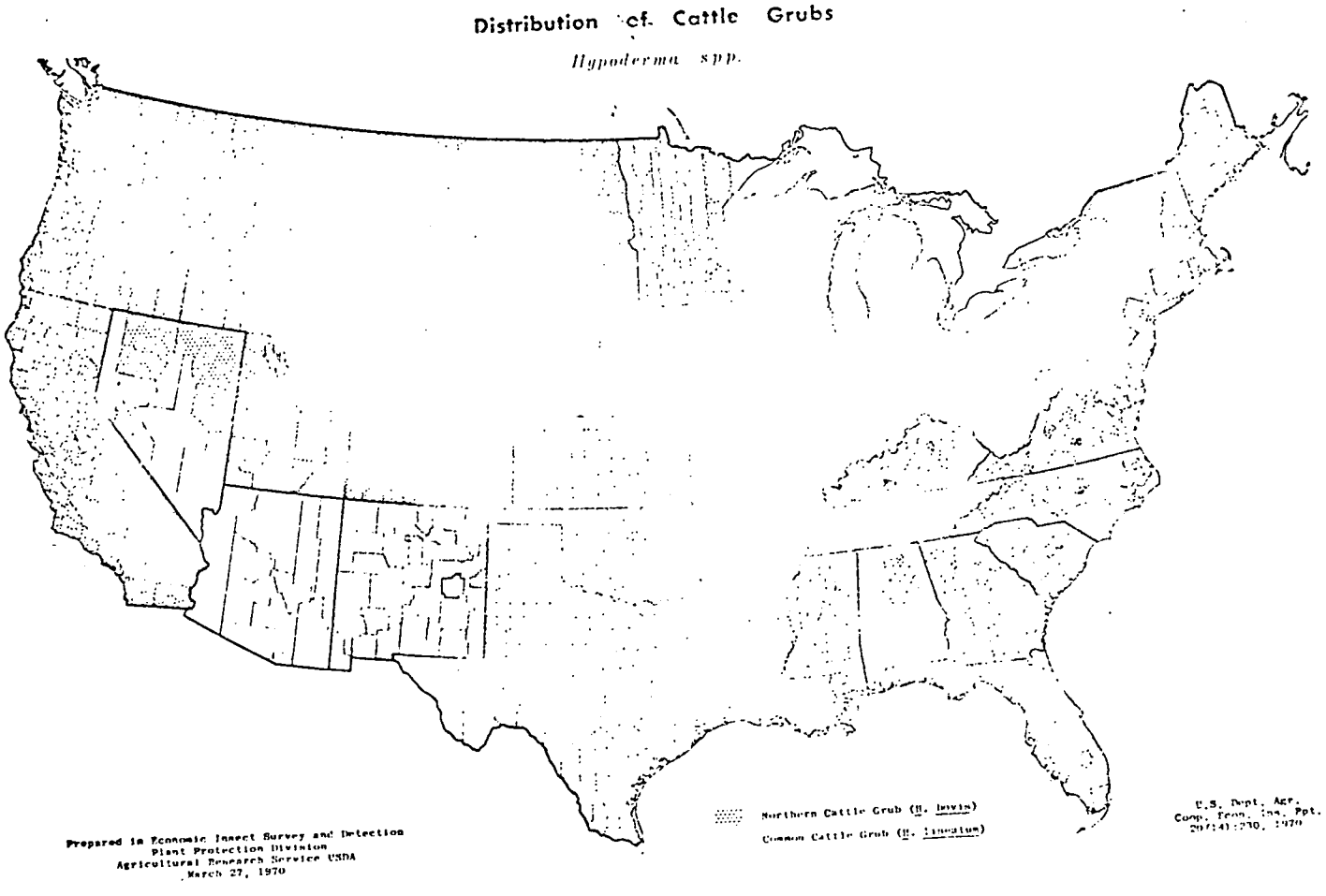
As seen in Table 5-10, Texas leads all other states in the number of livestock on ranches and farms. In this state, since the latest enactment of the quarantine in 1971, 3.5 million head of beef cattle have been dipped through March of this year. The estimated cost of the toxaphene dip used is $.10 per head ($350,000 for the period in question). The cost

to the ranchers, though, is estimated at $10 per head - including trim loss at slaughter, labor, moving cost, and potential weight loss - for a total of $35 million.

Toxaphene's use is also aimed at controlling horn fly, stable fly, face fly, lice, and tick problems in various types of livestock. For these purposes it is usually applied as a spray or backrub and has a 3 to 4 week period of effectiveness. Alternatives suggested for control of these pests include coumaphos, cydrin, dioxathion, ronnel, delnav, and corlan. All of these are more expensive than toxaphene (delnav would cost $.20 per application per head) and their period of effectiveness is 2 to 3 weeks implying the necessity of more frequent applications.

Many ranchers are now turning away from the use of toxaphene and turning to a systemic insectidice instead. Toxaphene controls the biting lice that irritate the livestock while the systemic controls both sucking lice and cattle grubs in one application. These systemics do necessitate more frequent applications and therefore a larger cost due to the cost of rounding up the livestock more ofter, but this may be worth it as it is estimated that there is a 25 percent weight loss if the sucking louse is uncontrolled and cattle grub is a problem throughout most of the country. (See Figure 5-2.)

Figure 5-2.


Distribution of Cattle Grubs
Hypoderma spp.
Northern Cattle Grub (H. bovis)
Common Cattle Grub (H. lineatum)
Prepared in Economic Insect Survey and Detection
Plant Protection Division
Agricultural Research Service USDA
March 27, 1970
U.S. Dept. Agr.
Coop. Econ. Ins. Rpt.
20(14):230, 1970

Minor Uses of Toxaphene

Ranking third and fourth in toxaphene usage are soybeans and peanuts, with usage in 1971 at 1.5 million pounds and 1.4 million pounds, respectively. Production of soybeans in that year was 1,176 million bushels. Peanut production totalled 2,993 million pounds.

Since 1971, production of both these crops has increased considerably. Production of soybeans in 1973 was 1,567 million bushels, up 33 percent from 1971, with a yield of 27.8 bushels per acre on the 56.4 million acres harvested. Value of production was $8,849 million. Peanuts were up 15 percent over 1971. Yield was a record 2,299 pounds per acre from the harvested 1,499,700 acres. This was valued at $558 million.

The soybeans plant can withstand moderate foliage loss without serious yield reduction particularly if injury occurs to the plant before the pod is set. Insects that feed on the pods, however, can reduce yields significantly. Because soybeans can withstand some defoliation, the need for insecticides to control foliage feeders varies with locale and season depending upon insect population. The Southern states with their heavy populations of both foliage and pod feeding pests require treatment of their soybean acreage.

In an effort to control the foliage feeders armyworms, blisters beetles, cutworms, grasshoppers, and others - the usual practice is to apply toxaphene as needed when insects appear in damaging numbers. Lepidoptera can best be controlled by making applications when larvae

are small. The migrating insects (armyworms and grasshoppers) can often be controlled by spraying only the field margins to form a barrier to migration and, thus, obtaining protection of soybeans by treatment of a relatively small area of the field.

The major pod-feeding insect pests are the corn earworm and stink bugs. The corn earworm consumes the pods while stink bugs such the sap from the young beans reducing yield and quality. Control is usually required about the time of blossom fall when there are more than three worms or one stink bug present per foot of row.

In 1973 there were six states that each produced over 100 million bushels of soybeans - Arkansas, Illinois, Indiana, Iowa, Minnesota, and Missouri. Collectively these states produced 1,065 million bushels. In the Southeast, where pests flourish and insecticide use on soybeans is historically the highest, production totalled 69 million bushels, four percent of the United States total for that year.

Carbaryl's usage in terms of poundage is almost equal to that of toxaphene in the control of soybean pests, despite the fact that it is reportedly less effective against all except for the Mexican bean beetle. It is also quite toxic to honeybees and is reported to encourage mite buildup and is phytotoxic to some varieties of soybeans. Malathion and methoxychlor are used but are generally not effective in the control of mixed populations of insects. Ethyl or methyl parathion are effective against stink bugs by themselves, but are normally used in combination with toxaphene to reduce the number of required applications and provide control of other insects present.

Major peanut pests include corn earworms, cutworms, armyworms, green cloverworms, leaf hoppers, stink bugs, thrips, and velvet bean caterpillars. The nature of injury produced by insects on peanuts is similar to soybeans. In addition, thrips may cause damage to seedling and young peanut plants by their feeding which causes malformation of leaves, and injury and destruction of terminal buds. In short, growth is retarded and yield reduced. The nymphs and adults of the leafhopper such the sap from the plants reducing vigor, growth, and ultimately, yield.

For thrip control two to three pounds of toxaphene per acre in the form of an emulsion is applied to the foliage of the seedling or young plants. For leaf hoppers, applications are started in mid-July and continued at 3-week intervals.

The big producing area of peanuts, the Southeast, is historically the area with the largest usage of insecticides on the crop. Georgia alone produced over one billion pounds of peanuts in 1973 with the four states in the Southeast together producing 1,921,550,000 pounds and using 14 percent of all insecticides on peanuts (based on 1971 usage). Virginia and North Carolina produced a record large crop of 766 million pounds. The Appalachian states, including Virginia and North Carolina, are the second largest area user of insecticides on peanuts.

Carbaryl is the only material approaching the broad spectrum of insect control by toxaphene on peanuts. Diazinon, methoxychlor, and malathion may be used as substitutes, but their periods of effectiveness are shorter necessitating more frequent applications to attain the required control.

In 1971 about two percent of the crop usage of toxaphene was on vegetables, including cabbage, carrots, celery, lettuce, onions, tomatoes, sweet corn, and so forth. It was used in an effort to control such pests as armyworms, cutworms, thrips, flea beetles, corn earworm, cabbage loopers, grasshoppers, tomato fruit worms and tomato russet mites. For the period 1951 to 1960 the estimated average annual loss to all vegetables due to insects was $185 million.

The 1972 value of production for the 22 vegetables and melons monitored by the Crop Reporting Board, SRS, USDA, was $1.8 billion, an increase of $.4 billion from 1971. Planted acreage in 1973 was 1,718,960 acres, an increase of 2 percent over the 1971 acreage.

A general, broad spectrum substitute for toxaphene on vegetables is methomyl (Lannate). For certain specific pests various substitutes are available: diazinon and malathion for thrip control; flea beetle control may require the use of carbaryl and methoxychlor in the absence of toxaphene; endosulfan, methoxychlor and naled on blister beetles; carbaryl for corn earworm on sweet corn; and parathion or dusting sulfur and the tomato russet mite.

Small grains accounted for 1.4 percent of the crop usage of toxaphene in 1971. The pests at which its use is directed include armyworms, grasshoppers, mormon cricket, and the rice stink bug on rice. The 1951 to 1960 estimated annual loss due to insects on wheat, barley, and oats was 6.1 percent. Damage to rice by the stink bug was estimated to be approximately three percent.

Armyworms fluctuate greatly, undergoing cycles which reach destructive peaks at varying periods. Damage is done by the larvae in the form of consuming the foliage and young grain heads. These pests mass migrate from field to field so that spraying the field margins to create barrier strips may help prevent this trend. Cutworms feed on foliage and cut off the plants at the soil line. Toxaphene is applied as an emulsion spray to plants and the soil surface.

Grasshoppers lay their eggs in the fall, usually confining this to limited areas of uncultivated land or clover, alfalfa and stubble fields. Spraying of these hatching areas is the most economic method of control since, when the grasshoppers are small, they are easily killed. When they reach the migrating stage, the method of creating barrier strips may be employed. Application of toxaphene for armyworm and cutworm control will also provide control for grasshoppers.

The rice stink bug does its damage by sucking the contents from the developing rice grains, leaving an empty seed coat or a discolored spot on the seed lowering yield and quality. Toxaphene is applied as an emulsion spray to control this pest.

Carbaryl is a possible substitute for the use of toxaphene on all these pests of the small grains. Major disadvantages to its use as compared to the use of toxaphene include a shorter period of effectiveness, higher toxicity to beneficial insects (bees, in particular), and more variability of effectiveness of control with varying weather conditions.

Ethyl and/or methyl parathion are suggested as substitutes in control efforts of several of these pests.

Appendix Tables

Table A-1

Effectiveness of Several Insecticides and Combinations (with and without DDT) 1/ Applied As Sprays Against the Bollworm and the Boll Weevil, Florence, S.C., 1967

Insecticide (lbs. a.i./acre)	Seasonal Square Infestation: % punctured by boll weevils	% injured by boll worms	% bolls injured by boll worms	Yield of seed cotton/ acre (lb.)
	1967, 18 applications, July 6 to Oct. 5			
Methyl parathion, 0.75	12 a	4.0 a	14.9 a	875 b
Methyl parathion + DDT, 0.75 + 1.0	8 ab	1.8 bc	5.5 bc	1461 a
Toxaphene + methyl parathion, 2.0 + 0.75	7 ab	2.2 b	6.2 b	1220 ab
Toxaphene + DDT, 2.0 + 1.0	10 a	1.0 cd	5.4 bc	1380 a
Toxaphene + DDT, + methyl parathion, 2.0 + 1.0 + 0.75	5 b	0.7 d	2.6 c	1514 a

1/ Means followed by the same letters are not significantly different according to Duncan's multiple range test at the 5% level.

Source: "Evaluation of Substitutes for DDT in Field Experiments for Control of the Bollworm and the Boll Weevil in Cotton: 1967-69", A. R. Hopkins, et. al., Journal of Economic Entomology, Vol. 63, No. 3, pp. 848-850.

Table A-2. Comparison of yields from insecticidal treatments for pink bollworm control. Phoenix, 1967.

Treatment	Rate lb./A	Mean Plot Yields	Stat. Sig. 5%	1%
Check	____	201.0	a	a
Thuricide	2 qts.	285.0	b	b
Toxaphene-Dylox	3-1.5	355.0	c	c
Mobam	1.0	358.5	c	c
Methyl Parathion	0.5	378.5	cd	cd
CP 47114	1.0	395.0	cd	cd
Toxaphene-Methyl Parathion	3-.63	396.5	cd	cd
GC 6505	1.0	413.5	de	cde
Toxaphene-Azodrin	3-.63	418.0	de	cde
Azodrin	0.63	430.5	de	cde
Toxaphene-DDT	4-2	431.5	de	cde
Toxaphene-Azinphosmethyl (Guthion)	3-1	453.0	ef	de
Azinphosmethyl (Guthion)	1.0	485.5	f	e

[1] Duncan's Multiple Range Test; treatment means followed by the same letter are not significantly different.

Source: "Evaluation of Insecticides for Pink Bollworm Control," T. F. Watson and D. G. Fullerton in Progressive Agriculture in Arizona, Vol. XXI, No. 2, pp. 4-6.

Table A-3. Effectiveness of insecticides for Heliothis control, Experiment 4, College Station, 1970 1/

Treatment and dosage	Percent Heliothis Damage 2/ seasonal average		Seed cotton per acre 3/
	Squares	Bolls	
Toxaphene-methyl parathion (2.0-1.9 lb per acre)			
ULV	9.9 4/	11.5	788
Conventional emulsion	15.0	12.8	705
Methyl parathion (1.5 lbs. per acre)			
ULV	10.0 4/	9.6 4/	837
Conventional emulsion	17.1	18.7	616
Outside Check	35.0	23.2	

1/ Main plots 0.25 acre, 32 rows wide, 4 replications of 4 treatments; 4 applications of insecticides from July 27 to August 17, 1970.

2/ Heliothis infestation 52% tobacco budworm and 48% bollworm.

3/ Estimated from boll counts.

4/ Significantly less than paired figure for conventional spray.

Source: "Field Tests of Chemicals for Control of Tobacco Budworms and Bollworms on Cotton, College Station," R. L. Hanna, in Investigations of Chemicals for Control of Cotton Insects in Texas, 1970-71, Texas A&M University - Texas Agricultural Experiment Station.

Table A-4

Insecticide	(Pounds A.I./Acre)	Yield Seed Cotton/Acre (Pounds) 1/	
Control (untreated)		695.25	c
Methyl Parathion	(1.0)	1844.75	ab
Toxaphene + Methyl Parathion	(3.0 + .75)	1962.75	a
Methyl Parathion (encapsulated)	(1.0)	1608.25	ab
Galecron + Methyl Parathion	(.25 + 25)	1641.50	ab

1/ Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Source: North Carolina State University Experiment - Insecticide Screening Test, Rocky Mount, North Carolina, 1971

Table A-5. Effectiveness of insecticides for Heliothis control in cotton (summary -- 5 replications) Experiment 2, College Station, 1971

Insecticide	Lbs. per Acre	Percent Heliothis1/ Injury Squares2/	Bolls2/	Yield Lbs.2/ Seed Cotton
Methomyl Dust	0.5	7.6 a	2.0 a	1340 ab
	1.0	8.6 ab	2.3 a	1437 a
Galecron -- Fundal	1.0	14.8 cd	7.5 ab	1205 abc
Phosvel (ULV)	1.5	11.9 bc	7.9 bc	1126 bcd
M. Parathion (Encapsulated)	1.5	13.4 bcd	8.2 bc	1061 cd
M. Parathion (ULV)	1.5	15.5 cd	9.6 bc	928 cd
Mobam (MCA 600)	1.5	14.8 cd	11.5 bc	936 cd
M. Parathion EPN	1.0-0.5	19.5 cd	12.8 bc	946 cd
Toxaphene M. Parathion	2.0-1.0	16.5 cd	15.1 bc	860 d
M. Parathion (Encapsulated)	0.8	19.1 d	17.8 c	844 d
Orthene	1.5	16.7 cd	17.8 c	928 cd
Check		38.4 e	27.3 c	418 e

1/ Percentages of bollworms and tobacco budworms estimated by collecting eggs weekly and rearing for identification as larvae. Eggs collected 7/20 were 34% tobacco budworm; 8/2, 23%; 8/10, 51%; 8/16, 75%; 8/23, 95%.

2/ Means of 3 May-planted and 2 July-planted plots. Statistical separation of means based on analysis of variance and Duncan's multiple range test.

Source: "Field Tests of Chemicals for Control of Tobacco Budworms and Bollworms on Cotton, College Station," R. L. Hanna, in Investigations of Chemicals for Control of Cotton Insects in Texas, 1970-71, Texas A&M University - Texas Agricultural Experiment Station.

Table A-6. Yield in pounds of lint per acre at five field locations, and the average yield of the five fields in relation to the insecticide treatment and yield in equivalent untreated check plots.

Treatment[1]	Field Number 1	2	3	4	5	Average Yield/Acre[2]	Average Number Treatments
Untreated check	857	1084	1053	1133	1227	1071 a	0
Bacillus thuringienses	914	992	1053	1139	1006	1021 a	8.8
Sevin 15/100	881	1085	1037	990	1134	1025 a	4.2
Methyl parathion	747	1020	875	1198	996	949 ab	7.0
Sevin 8/100	760	976	839	1076	584	847 b	8.2

Source: "Bollworm Control 1969", J. Hodge Black, in Kern Cotton, April 12, 1971.

[1]TREATMENTS AS FOLLOWS: (a) Untreated check - early season lygus and mite control as needed (all plots in each field treated the same); (b) Bacillus thuringiensis applied as needed based upon worm counts; (c) methyl parathion applied as needed based on worm counts; (d) sevin and sulfur dust at 4 pds active sevin per acre (applications made at 15 small worms per 100 plants as needed); (e) sevin and sulfer dust at 4 pounds active per acre (applications made at 8 small worms per 100 plants as needed).

[2]Means followed by the same letter do not significantly differ as indicated by Duncan's multiple range test.

Entomologists Contacted

Cotton

1. Dr. Roy J. Lebetter, Department of Zoology-Entomology, Auburn University.
2. Dr. T. F. Watson, Department of Entomology, University of Arizona, Tucson.
3. Gordon Barnes, Extension Entomologist, University of Arkansas, Little Rock.
4. Dr. W. G. Eden, Department of Entomology, Florida State University.
5. Dr. Tandarday, Field Entomologist, University of Georgia, Tifton.
6. Dr. R. A. Scheibner, Department of Entomology, University of Kentucky.
7. Drs. L. D. Newsome and D. F. Clower, Department of Entomology, Louisiana State University.
8. Jim Hamer, Extension Entomologist, Mississippi State University.
9. Dr. R. L. Robertson, Department of Entomology, North Carolina State University.
10. Dr. D. C. Peters, Department of Entomology, Oklahoma State University.
11. Dr. L. M. Sparks, Department of Entomology, South Carolina State University.
12. Drs. Ray Frisbie and Lynn Hanna, Extension Entomologist and Associate Professor, Texas A&M University.
13. Vernon Burton, Extension Entomologist, University of California-Davis.

Livestock

1. Dr. W. C. Clymer, Area Entomologist, Texas A&M University, Amarillo.
2. Dr. H. L. Brooks, Department of Entomology, Kansas State University.
3. Dr. J. F. Butler, Department of Entomology and Nematology, University of Florida.
4. Dr. Gen Schubert, Chief Staff Veterinarian, Animal Health Division, APHIS.
5. W. M. Hantsbarger, Department of Zoology-Entomology, Colorada State University.
6. Dr. G. D. Thomas, Department of Entomology, University of Missouri-Columbia.
7. Dr. J. B. Campbell, Department of Entomology, University of Nebraska.
8. Dr. Wayne Berndt, Extension Entomologist, South Dakota State University.
9. Dr. J. E. Lloyd, Division of Plant Science-Entomology Section, University of Wyoming.

Strobane

A chlorinated hydrocarbon pesticide, strobane is very similar to toxaphene. It came into some prominence during the 1960's for use on cotton and, to some extent, as a mothproofer and household insecticide.

Farm use of strobane for 1966 and 1971 is summarized in Table . In 1966 its use was reported in the Appalachian, Delta, and Southeast regions, the largest amount (97 percent) in the Delta states of Arkansas, Louisiana, and Mississippi. Its use in 1971 was reported in the Appalachian and Mountain regions. All of its farm use for each of these survey years was reported for cotton pest control.

Table

Quantities of Strobane Used on Crops and Acres Treated, 1966 and 1971

Year	Pounds Active Ingredient -1,000-	Acres Treated -1,000-
1966	2,016	225
1971	216	18

Source: Quantities of Pesticides Used by Farmers, 1966 and 1971, USDA-ERS.

The principle registered uses of strobane are on cotton, usually in formulations with DDT, methyl parathion, or both. It is applied in rates of 1 to 4 pounds active ingredient per acre. A tolerance level of 5 ppm has been established on cotton seed for strobane's use. Its pesticidal efficacy appears to be quite close to that of toxaphene. See Table .

In a concentration of 5 percent strobane has been registered as a mothproofer for the treatment of woolens and fabrics subject to damage by fabric pests. A 2 percent concentration is registered for use as a household insecticide when combined with synergized pyrethrin and other ingredients. Strobane is used as a residual ingredient in pesticides for use in commercial premises outside of the edible products area. Another registered use is in a 3 percent concentration for purposes of embalming.

The only remaining producer of strobane is Tenneco, Incorporated. Indications are, however, that they have not produced any in the last five years. Thus, any strobane that is being used is from the surplus built up when it was in production or from importation. As a proprietary chemical, importation figures are unavailable.

Table

Comparison of Effectiveness of Conventional Low-Volume Sprays of Certain Insecticides Against Adult Boll Weevils Cared on Treated Plants, College Station, 1968

Insecticide(s)	Insecticide(s) Actual toxicant, pounds per acre	Percent kill, 48 hours [1]
Guthion	0.25	100 a
Methyl parathion	0.25	100 a
Azodrin-M. parathion	0.3125-0.25	100 a
EPN-M. parathion	0.25-0.25	100 a
Guthion (ME)-M. parathion	0.09-0.375	100 a
EPN-M. parathion	0.125-0.125	98 a
EPN	0.25	97 a
Azodrin	0.625	95 a
Strobane-M. parathion	1.0-0.25	93 a
Toxaphene-M. parathion	1.0-0.25	93 a
Malathion	1.0	78 ab
Sevin	1.6	68 bc
Toxaphene-DDT	2.0-1.0	48 d

[1] Means designated by the same small letters are equal and are different from all other means at the 5-percent level of probability.

Source: Nemec, S.J. and Adkisson, P.L. "Laboratory Tests of Insecticides for Bollworm, Tobacco Budworm and Boll Weevil Control" in Investigations of Chemicals for Control of Cotton Insects in Texas, 1968, Texas A&M University, Texas Agricultural Experiment Station.

CHAPTER VI

Summarized Review of the Use of Toxaphene and Strobane in Relation to the Hazards or Safety of Continued Use.

VI.A. Toxaphene:

Toxaphene insecticides, as developed by the Hercules Powder Company of Wilmington, Delaware, have been registered for a variety of purposes on agricultural crops, in premises, and on livestock since the early 1950's. The earliest registrations were on vegetable and forage crops. However, agricultural uses expanded rather rapidly to include many fruits, vegetables, and field crops, including the small grains. However, usage on animal feed crops did not persist since it was not possible to obtain necessary tolerances in milk and poultry products. Tolerances on a considerable number of fruits and vegetables were established as well as in the fat of meat of slaughter animals and on the principal small grains.

Table VI.A. contains the registered uses, tolerances and registered substitutes for toxaphene. It will be noted that there are tolerances of seven parts per million on a considerable variety of fruits and vegetables as well as in the fat of meat of cattle, goats, hogs, horses, and sheep. In addition, there are tolerances of 5 parts per million on a variety of small grains and on cotton seed, as well as certain tolerances for toxaphene alone or mixed with DDT on soybeans. Clearances for use on bananas is also noted. However, usage on fruit and vegetable crops has never expanded to any great extent. In

recent years, major uses of this pesticide have been combined with DDT to control a variety of insect pests on cotton, including the boll weevil and bollworm; as water-based dips and sprays for biting flies, ticks and lice on slaughter livestock, and the last two for corn earworm and other leaf-eating insects on peanuts and soybeans.

Although certain home mothproofing treatments were registered, the household applications never became important. Similarly, soil treatments and lawn applications never became major uses.

Toxaphene is a relatively persistent complex chlorinated hydrocarbon insecticide with a fairly broad spectrum of toxicity to leaf-eating pests and external parasites of animals. It has not created any major problem of environmental pollution, although it has a relatively high toxicity to fish.

TABLE VI.A.

REGISTERED USES OF TOXAPHENE

Crop or Site of Application	Tolerance (ppm or non-food)	Dosage lbs. per Acre or Concentration	Limitations	Pests	Registered Substitutes
SEED TREATMENT: VEGETABLES					
Barley, Oats, Rice, Rye Wheat	NF	2.0 oz/bu. seed	Seed treatment. Do not use as food or feed.	Seed-corn maggot wireworms	chlordane, heptachlor, lindane
Beans					
(Green, velvet, Lima, snap)	NF	2.0 oz/bu. seed	Seed treatment. Do not use treated seed for food or feed.	Seed-corn maggot wireworms	chlordane, diazinon, heptachlor, lindane
Cowpeas	NF	2.0 oz/bu. seed	Seed treatment. Do not use as food or feed.	Seed-corn maggot wireworms	chlordane, lindane
Peas	NF	2.0 oz/bu. seed	Seed treatment. Do not use as food or feed.	Seed-corn maggot wireworms	chlordane, diazinon, lindane
Sorghum	NF	2.0 oz/bu. seed	Seed treatment. Do not use as food or feed.	Seed-corn maggot wireworms	heptachlor, lindane
Soybeans	NF	2.0 oz/bu. seed	Seed treatment. Do not use as food or feed.	Seed-corn maggot Wireworms	diazinon, heptachlor, lindane

TABLE VI.A. (cont'd.)

Crop or Site of Application	Tolerance (ppm or non-food)	Dosage lbs. per Acre or Concentration	Limitations	Pests	Registered Substitutes
FOLIAGE TREATMENT: FRUITS AND NUTS					
Apples	7	16.0	Do not apply after second cover spray or within 40 days of harvest.	Eastern tent caterpillar Grasshoppers	carbaryl, lead arsenate, malathion, methoxychlor, parathion
Apricots	7	12.0	Do not apply after second cover spray or within 40 days of harvest.	Grasshoppers caterpillar Grasshoppers	parathion malathion, methoxychlor, parathion
Bananas	3 (not more than 0.3 in pulp)	1.5 (3 pints of 80% liquid concentrate/A)	1 day. Apply by aircraft as ultra-low volume (undiluted spray.	Leaf eating caterpillars Ceramidia species	trichlorfon

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Bananas (Cont.)			Do not graze treated area to dairy animals or animals being finished for slaughter.	Leaf eating caterpillars Ceramidia species	trichlorfon
		50.0	To be applied to trunk and soil. Do not apply when fruit is present. Do not feed treated forage to dairy animals or animals being finished for slaughter. Single application.		
		5.0	Wet or dry bait formulations. Do not apply broadcast when edible parts are present.		
Peaches Nectarines	7			Oriental fruit moth Thrips Lygus bugs Plum curculio	carbaryl, chlordane, Guthion, EPN, malathion, methoxychlor, parathion, lindane
Pears	7	16.0	Dust or spray. Do not apply within 40 days of harvest, or after second cover spray.	Grasshoppers Pear psylla Red-banded leaf roller Lygus bugs Oriental fruit moth Thrips	parathion Furadan, Guthion, lindane, Morestan, Perthane, summer oil carbaryl, Furadan, Guthion, lead arsenate, malathion, Ryania, parathion carbaryl, Phosdrin, parathion

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Quinces	7			Grasshopper	parathion
				Red-banned leaf roller	carbaryl, Cardona, Naradan, lead arsenate, malathion, parathion, ryania
				Lygus bugs	
				Oriental fruit moth	
				Thrips	
Hickory nuts	7	10.0	Dust or spray. No time limitations.	Pecan weevil	
Pecans	7	10.0	No time limitations.	Pecan-nutcase bearer	EPN, guthion, malathion, parathion, Thiodan
				Pecan weevil	EPN
				Spittle bugs	Guthion, parathion, Thiodan
				Walnut caterpillar	
				Fall webworms	
Walnuts	7	1.50	Dust or spray. No time limitations.	Walnut caterpillar	
FOLIAGE TREATMENT: VEGETABLES					
Beans (dry, green, lima)	7	6.0	No limitations on use of shelled beans as human food. Do not apply dusts to green or snap beans within 7 days of harvest. Do not apply sprays to green or snap beans after pods begin to form. Do not feed treated vines to dairy animals or animals being finished for slaughter.	Armyworms	carbaryl, methyl parathion, parathion, trichlorfon
				Mexican bean beetle	carbaryl, diazinon, EPN, Guthion, malathion, methoxychlor parathion, Phosdrin, rotenone, Trithion, Phosphamidon, trichlorfon

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Beans (dry, green, lima) (CONT.)				Bean leaf hopper	carbaryl, naled, diazinon, malathion, methoxychlor, methyl parathion, parathion, Phosdrin
Broccoli Brussels Sprouts	7	8.0	Do not apply after edible parts begin to form or within 30 days of harvest.	Armyworms	carbaryl, methyl parathion, parathion
				Cabbage looper	naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Imported cabbage worm	carbaryl, naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Thrips	lindane, methyl parathion, parathion
				Serpentine leaf miner	Phosdrin
				Cabbage caterpillar	malathion
				Cabbage worm	synergized pyrethrins
				Diamondback moth	synergized pyrethrins
				Corn earworm	diazinon
				Cutworms	Dylox bait
				Flea beetles	synergized pyrethrins
				Green peach aphid	diazinon

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Broccoli Brussels Sprouts (Cont.)				Field crickets Salt marsh caterpillar Grasshoppers Stink bugs Tortoise beetle Vegetable weevil Aphids	
Celery	7	5.0	Do not apply after plants start to bunch or after plants are half mature.	Cabbage worms	lindane, malathion, parathion, Phosdrin, Thiodan
				Celery leaf tier	lindane, parathion, pyrethrins
				Cutworms	lindane, Phosdrin
				Fall armyworms	naled
				Serpentine leaf miner Thrips Vegetable weevil	Phosdrin
				Leaf miner	parathion
				Imported cabbage worm	
				Green peach aphid	synergized pyrethrins, Thiodan
				Loopers Armyworms	
Citrus: Grapefruit Kumquats Lemons, Limes Oranges Tangelos Tangerines	7	10.0	30 days. Dust, spray or granular formulations. Do not feed treated forage to dairy animals or animals being finished for slaughter.	Cutworms Fire ant	
				Fruit tree leaf roller Thrips	diazinon
				Western Tussock moth	parathion, carbaryl

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Citrus: (Cont.)				Grasshoppers	
		5.0	Wet or dry bait formulation. Do not apply broadcast when edible parts are present.	Cutworms	chlordane
				Grasshoppers	chlordane
		5.0	To be applied as a soil treatment when no fruit is present. Do not feed treated forage to dairy animals or animals being finished for slaughter. Single application.	Cutworms	chlordane
				Grasshoppers	chlordane
Collards Kale	7	2.0	14 days. (dust) 28 days. (spray)	Army worms	carbaryl, methoxychlor, parathion
		4.0	21 days, (dust) 35 days, (spray)	Cabbage looper	Bacillus thuringiensis, naled, lindane, malathion, parathion, Phosdrin, Thiodan
Corn	7	2.0	Granular formulation only. Do not feed ensilage from treated corn to dairy animals or animals being finished for slaughter. Do not graze dairy animals on treated stover within 4 weeks of slaughter. No limitation on use of grain.	European corn borer	carbaryl, diazinon, EPN, parathion, ryania

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Corn (Cont.)		6.0	Do not feed treated forage to dairy animals being finished for slaughter. No limitations on use of grain.	Armyworms	carbaryl, methyl parathion,
				Corn earworm	carbaryl, chlordane, diazinon, methoxychlor
Cotton	5 (cottonseed)	4.0	Do not graze dairy animals or animals being finished for slaughter in fields treated late in the season.	Boll weevil	chlordane, endrin, EPN, Guthion, malathion, methyl parathion, methyl trithion, Strobane
				Bollworm	Azodrin, carbaryl, endrin, EPN, methyl parathion, Strobane
				Beet armyworm	methyl parathion, trichlorfon
				Cotton leaf perforator	Bidrin, carbaryl, malathion, methyl parathion, Methyl Trithion, parathion, trichlorfon
				Cotton leaf worm	carbaryl, Guthion, endrin, malathion, methyl parathion, Methyl Trithion, parathion, trichlorfon
				Cutworms	carbaryl, endrin, Strobane, trichlorfon
				Fall armyworms	carbaryl, chlordane, endrin, methyl parathion, Strobane
				Fleahoppers	Bidrin, carbaryl, chlordane, naled, endrin, Guthion, malathion, methyl parathion, parathion

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cotton (Cont.)				Flea beetles	endrin, trichlorfon
				Garden webworm	carbaryl, endrin, Guthion, malathion, methyl parathion, Strobane
				Grasshoppers	carbaryl, chlordane, malathion, methyl parathion, Strobane
				Lygus bugs Mirids	Bidrin, carbaryl, chlordane, endrin, malathion, methyl parathion, parathion, phosphamidor, Strobane, trichlorfon
				Stink bugs	carbaryl, methyl parathion, parathion, Thiodan, trichlorfon
				Thrips	Bidrin, carbaryl, endrin, malathion, methyl parathion, Methyl Trithion, parathion, phosphamidon, Strobane
				Yellow striped armyworm	endrin, methyl parathion, trichlorfon
				Leaf worm	diazinon
				Armyworm	Dylox bait
				Webworms	
				Darkling ground beetles	trichlorfon

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cotton (Cont.)				Leaf tier Pink bollworm Cabbage looper Tobacco budworm Horn worm	
		8.0	Do not apply after bolls open.	Garden webworm	carbaryl, endrin, Guthion, malathion, methyl parathion, Strobane
				Western yellow-striped armyworm	Dylox bait
		4.0	Apply with DDT as an undiluted (low volume) spray by aircraft. Do not graze dairy animals or animals being finished for slaughter on treated areas. Do not feed treated cotton trash to dairy animals or animals being finished for slaughter.	Stink Bugs	carbaryl, methyl parathion, Thiodan, trichlorfon
Cowpeas	7	3.0	No limitation on use of shelled peas as human food. Do not apply to cowpeas to be used as green snaps after pods begin to form. Do not feed treated vines to dairy animals or animals being finished for slaughter.	Bean leaf hopper	carbaryl, malathion, methoxychlor, parathion
				Bean leaf roller	carbaryl, methoxychlor, parathion
				Cowpeas curculio	carbaryl, Guthion, Thiodan
				Cutworms	carbaryl
				Darkling ground beetles	
				Lygus bugs	malathion
				Southern green stink bug	Guthion, parathion

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cranberries	7	5.0	Do not apply after fruit starts to form.	Armyworms	
				Grasshoppers	carbaryl
Cucumbers	7	3.0	Do not apply after edible parts start to form. May be injurious to plant growth.	Cucumber beetles	carbaryl, Guthion, malathion, lindane, methoxychlor, parathion, Thiodan
				Flea beetles	parathion
Eggplants	7	3.0	5 days.	Armyworms	carbaryl
				Blister beetle	naled, parathion, Thiodan
				Colorado potato beetle	carbaryl, methoxychlor, parathion, Thiodan
				Cucumber beetles	
				Cutworms	carbaryl
				Flea beetles	carbaryl, naled, lindane, parathion, Thiodan
				Leaf hoppers	
				Serpentine leaf miner	naled, lindane, parathion
				Vegetable weevil	
		6.0	Do not apply after edible parts start to form.		

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Kohlrabi	7	8.0	Do not apply after edible parts begin to form or within 30 days of harvest.	Corn earworm	
				Cutworms	methyl parathion, trichlorfon
				Imported cabbage-worm	Bacillus thuringiensis, carbaryl, naled, lindane, malathion, parathion, Phosdrin, Thiodan
				Thrips	lindane, methyl parathion, parathion
				Serpentine leaf miner	Phosdrin
				Diamondback moth	
				Flea beetles	
				Salt marsh caterpillar	
				Grasshoppers	
				Stink bugs	
				Tortoise beetles	
				Crickets	
Lettuce	7	5.0	Do not apply after seedling stage on leaf lettuce. Do not apply after heads begin to form on head lettuce.	Armyworms	carbaryl, naled, parathion, Phosdrin, trichlorfon
				Cabbage looper	Bacillus thuringiensis, naled, methyl parathion, malathion, parathion, Phosdrin, Thiodan
				Cabbage worms	naled, malathion, parathion, Phosdrin, Thiodan, trichlorfon
				Cucumber beetles	parathion, Phosdrin
				Cutworms	Phosdrin, trichlorfon
				Field crickets	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Lettuce (Cont.)				Flea beetles	carbaryl, methyl parathion
				Grasshoppers	Phosdrin
				Salt marsh caterpillars	naled, Phosdrin, trichlorfon
				Thrips	allethrin, Di-Syston
				Loopers	Thiodan, allethrin, Perthane
				Stink bugs Tortoise beetle Vegetable weevil Psyllids Lygus bugs False chinch bugs Webworms	
Okra	7	5.0	Do not apply after pods begin to form.	Cutworms	Phosdrin
				Serpentine leaf miner	parathion
				Thrips Crickets Tortoise beetles Armyworms Salt marsh caterpillars Cabbage looper Grasshoppers Stink bugs	
Peas	7	5.0	Do not apply after pods begin to form if pods are to be used as food, or within 7 days of harvest of pods are not to be used as food. Do not feed vines to dairy animals or animals being fattened for slaughter.	Leaf miners	parathion, dimethoate
				Lygus bugs	methyl parathion
				Armyworms Cutworms Fall armyworms Flea beetles Vegetable weevils Cowpea curculio	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Peppers	7	3.0	5 days.	Armyworms	carbaryl, methyl parathion
		6.0	Do not apply after peppers begin to form.	Blister beetles	naled, parathion
Pimentos	7	2.0	2 days.	Colorado potato beetle	carbaryl, methoxychlor
		5.0	Do not apply after edible parts start to form.	Cutworms	carbaryl, methyl parathion
				Flea beetles	carbaryl, naled, methoxychlor, methyl parathion, parathion, Thiodan
				Fruit worms	carbaryl, methoxychlor
				Hornworm	carbaryl, parathion, Thiodan
				Pepper weevil	
				Serpentine leaf miner	diazinon, naled, dimethoate, lindane, parathion
				Loopers	
				Leafhoppers	methyl parathion
				Salt marsh caterpillar	
				Cabbage looper	
				Grasshoppers	
				Stink bugs	
				Tortoise beetle	
				Crickets	
				Vegetable weevils	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Pineapples	3	2.25	Apply when first whorl of flowers is open and repeat 7-10 days later. Do not feed waste from treated pineapples to dairy or meat animals.	Batrachedera species lepidopterans larvae (gunmosis)	
		20.0	Preplanting soil treatment at time of planting. Single application.	Batrachedera species lepidopterans larvae (gunmosis)	
Potatoes	Extended	6.0	Foliage treatment only. No time limiations.	Armyworms	carbaryl, diazinon, methyl-parathion, parathion, Phosdrin, Thiodan
				Colorado potato beetle	carbaryl, chlordane, diazinon, naled, Cathion, methoxychlor, parathion, phosphamidon, Thiodan
				Cutworms	parathion
				Foliar caterpillars	methyl parathion, parathion, Phosdrin
				Flea beetles	carbaryl, diazinon, naled, Cathion, methyl parathion, parathion, Thiodan
				Grasshoppers	malathion, parathion, Phosdrin
				Hornworm	carbaryl, parathion, Thiodan
				Leaf hoppers	carbaryl, naled, dimethoate, Cathion, malathion, methyl-parathion, parathion, Thiodan, Phosdrin

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Potatoes (Cont.)				Potato aphids	diazinon, naled, dimethoate, Cuthion, malathion, methyl parathion, Phosdrin, parathion
				Tortoise beetle	
				European corn borer	carbaryl
				Serpentine leaf borer	
				Salt marsh caterpillar	
				Cabbage looper Stink bugs Crickets Tomato russet mite Psyllids Blister bugs Lygus bugs False chinch bugs Webworms	
Rutabagas	7	6.0	Do not use treated tops for food or feed.	Cabbage worms	carbaryl, malathion, parathion
				Cutworms	chlordane
				Flea beetles	carbaryl, methoxychlor
				Spinach leaf miner Sugar beet webworm Armyworm Salt marsh caterpillar Cabbage looper Grasshoppers Stink bugs Tortoise beetle Crickets Tomato russet mite	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Sorghum	5	2.0	28 days. Do not apply more than once after heads start to form. Do not graze dairy animals or animals being finished for slaughter on treated fields. Do not ensile treated forage.	Chinch bugs	parathion
				Cutworms	methyl parathion, parathion, trichlorfon
				Corn lantern fly	
		3.0	40 days. Do not apply more than once after heads start to form. Do not graze dairy animals or animals being finished for slaughter on treated fields. Do not ensile treated forage.	Fall armyworms	carbaryl, diazinon, methyl parthion, parathion
				Grasshoppers	diazinon, methoxychlor, parathion
				Lesser corn stalk borer	diazinon
				Mormon crickets	
				Flea beetles	diazinon
				Crickets	
				Budworms	parathion
				Blister beetles	
				Sorghum webworm	
				Garden webworm	
				False chinch bug	
				Midge	
Soybeans	2.0 (soybeans dry form) 3.5 (combined toxaphene and DDT, toxaphene not to exceed 2.0 ppm) 6.0 (crude soybean oil)	3.0	Apply with DDT as an undiluted (ultra-low volume) spray by aircraft. Do not apply closer than 21 days before harvest. Do not make more than two applications after pods form. Do not feed plants treated with toxaphene-DDT or ensilage made from treated plants to poultry, dairy animals or animals being finished for slaughter.	Velvet bean caterpillar	
				Bollworm	
				Corn earworm	
				Bean leaf beetle	
				Armyworm	
				Grasshopper	
				Blister beetles	
				Green clover worm	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Soybeans (Cont.)			Do not feed soybean mill trash to livestock or poultry.		
		2-4lbs. (dust or spray)	21 days. Do not feed treated plants or ensilage made from treated plants to poultry, dairy animals or animals being finished for slaughter. Do not feed mill trash to livestock or poultry.	Velvet bean caterpillar Bollworm Corn earworm Bean leaf beetle Armyworm Grasshopper Blister beetle Green clover worm	
	2.0 (soybeans, dry form) 6.0 (crude soybean oil)	4.0		Armyworms	carbaryl, methoxychlor, parathion
				Bean leaf beetles	carbaryl, methyl parathion
				Blister beetles	carbaryl, methyl parathion, parathion
				Corn earworm	carbaryl methyl parathion, parathion
				Crickets	
				Flea beetles	methoxychlor
				Grasshoppers Green clover worm Lesser corn stalk borer	carbaryl
				Southern green stink bug	carbaryl, methyl parathion, Thiodan
				Thrips	carbaryl, malathion, parathion
				Velvet bean caterpillar	carbaryl, methoxychlor, methyl parathion, parathion
				Webworms	carbaryl, methyl parathion

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Soybeans (Cont.)				Alfalfa caterpillar Cutworms Mexican bean beetle Salt marsh caterpillar Bollworm Cabbage looper	
Spinach	7	4.0	Do not apply after seedling stage.	Alfalfa looper	methoxychlor
				Armyworms	carbaryl, naled, methyl parathion, parathion
		2.0	21 days. Do not apply more than once per season.	Cabbage worms	carbaryl, parathion, Phosdrin
				Cabbage looper	naled, methoxychlor, parathion, Phosdrin
				Cutworms	Phosdrin
				Green peach aphid	parathion
				Serpentine leaf miners	diazinon, naled, Guthion, lindane, parathion, Phosdrin
				Thrips	parathion
Strawberries	7	3.0	Do not apply after fruit starts to form.	Strawberry crown borer	chlordane
				Strawberry weevil	methoxychlor
				Thrips	malathion
				Cutworms Spittle bugs Lygus bugs	
Tobacco				Cutworms (plant beds)	Dipterex bait, methyl parathion

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Tomatoes	7	2.0	1 day.	Armyworms	carbaryl, diazinon, Guthion, methyl parathion, Phosdrin, parathion, Thiodan
		5.0	3 days.	Blister beetles	naled, methoxychlor, parathion, Thiodan
				Cabbage looper	Bacillus thuringiensis, naled, methyl parathion, Phosdrin, parathion, Thiodan
				Colorado potato beetles	carbaryl, naled, Guthion, lindane, malathion, methoxychlor, parathion, phosphamidon, Thiodan
				Cutworms	carbaryl
	7	2.0	1 day.	Flea beetles	carbaryl, chlordane, naled, Guthion, lindane, methyl parathion, parathion, phospha-midon, Thiodan
				Grasshoppers*	Guthion, Phosdrin, parathion
				Green chrysanthemum aphids	methyl parathion, parathion, Phosdrin
				Pinworms	carbaryl, Guthion, Thiodan
				Russet mites	naled, methyl parathion, Phosdrin, parathion
				Serpentine leaf miners	chlordane, diazinon, naled, dimethoate, Guthion, lindane, parathion, phosphamidon, trichlorfon
				Thrips	Guthion, lindane, parathion

*Two pound rate only.

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Tomatoes (Cont.)				Tomato fruit worm	carbaryl, cryolite bait, naled, Guthion, methoxychlor, Phosdrin
				Leaf miners	parathion
				Hornworms Crickets	
				Stink bugs	parathion
				Salt marsh caterpillar	
	7	2.0	1 day.	Tortoise beetle	
		5.0	3 days.	Vegetable weevil Tomato psyllid Corn earworm	
				Tomato horn worm	carbaryl, chlordane, naled, Guthion, Phosdrin, parathion, Thiodan, trichlorfon
FOLIAGE TREATMENT: BUSH AND VINE FRUITS					
Blackberries Boysenberries Dewberries	7	25.0	Preplanting soil treatment or when no fruit is present.	Cutworms	chlordane, heptachlor*
Loganberries		5.0	Wet or dry bait formulation. Do not apply broadcast when edible parts are present.		

*Not on loganberries.

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Alfalfa (Seed Production)	Extended	2.5	Apply in early spring or after cutting before new growth is 4 inches tall.	Alfalfa caterpillar	Bacillus thuringiensis, carbaryl, methyl parathion, methoxychlor, Phosdrin
FORAGE CROPS		3.5	Do not feed treated forage to dairy animals or animals being finished for slaughter.	Alfalfa leafhopper	carbaryl, Guthion, malathion, methyl parathion, methoxychlor
				Alfalfa looper	pyrethrins, rotenone
				Alfalfa weevil	diazinon, Guthion, Perodan, malathion, methoxychlor, methyl parathion, parathion, Phosdrin.
				Cloverleaf weevil	malathion, methoxychlor, methyl parathion
				Cutworms	methyl parathion, parathion, Phosdrin, trichlorfon
				Corn cutworm	
				Flea beetles	methoxychlor, methyl parathion
				Grasshoppers	carbaryl, diazinon, naled, malathion, Phosdrin
				Mormon crickets	
				Pea aphids	demeton, diazinon, Guthion, malathion, methyl parathion, parathion, Phosdrin, phosphamidon
				Plant bugs	Guthion, malathion, methyl parathion, Phosdrin, Phosphamidon, trichlorfon
				Spittle bugs	Guthion, malathion, methoxychlor, Thioden

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
FORAGE CROPS: Alfalfa (Cont.)				Stink bugs	
				Sweet clover weevil	
				Thrips	malathion, trichlorfon
				Webworms	methoxychlor, methyl parathion, parathion, trichlorfon
				Yellow striped armyworm	malathion, methoxychlor, methyl parathion, parathion, trichlorfon
				Green cloverworm	naled
				Leafhoppers	diazinon
				Alfalfa webworm	naled
				Tortrix moth	parathion
				Crickets Leafrollers Three-covered alfalfa hopper	
	Extended	25.0	Apply as a preplanting soil treatment or before edible parts start to form. Single application.	Cutworms	Dylox bait
Bush and Vine Fruits: Blackberries Boysenberries Dewberries Loganberries		4.0	Do not apply after fruit begins to form.	Cutworms	carbaryl

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cranberries	7	25.0	Preplanting soil treatment or when no fruit is present. Single application.		
		5.0	Wet or dry bait formulation. Do not apply broadcast when edible parts are present.		
Raspberries Youngberries	7	25.0	Preplanting soil treatment or when no fruit is present. Single application.		
		5.0	Wet or dry bait formulation. Do not apply broadcast when edible parts are present.	Cutworms	chlordane
				Grasshoppers	chlordane
Strawberries	7	25.0	Preplanting soil treatment or when no fruit is present. Single application.	Cutworms	chlordane, lindane
		5.0	Wet or dry bait formulation. Do not apply broadcast when edible parts are present.	Cutworms	chlordane
				Grasshoppers	chlordane
Raspberries	7	4.0	Do not apply after fruit begins to form.	Grasshoppers	carbaryl

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
SOIL AND BARK TREATMENT:					
Deciduous Fruits and Nuts: Apples, Apricots, Hazelnuts, Hickory nuts, Nectarines, Peaches, Pears, pecans, Quinces, Walnuts	7	25.0	Soil application. Apply to trunk, scaffold branches, and soil when no fruit is present. Do not feed treated forage to dairy animals or animals being finished for slaughter. Single application.		
		5.0	Wet or dry bait formulation. Do not apply broadcast when edible parts are present.	Grasshoppers	
FIELD AND FIBER CROPS: Barley, Oats, Rice, Rye, Wheat	5	25.0	Apply as a preplanting soil treatment or before edible parts start to form. Single application.	Cutworms	chlordane
Corn (field and pop)	7	25.0	Apply as a preplanting soil treatment or before edible parts start to form. Single application.	Cutworms	carbaryl, chlordane, diazinon, heptachlor, parathion
Rice	5	3.5	Do not feed treated forage to dairy animals or animals being finished for slaughter. No limitations on the use of	Armyworms	carbaryl, malathion, methyl parathion
				Chinch bugs	methyl parathion, parathion
				Cutworms	carbaryl methyl parathion
				Grasshoppers	chlordane, malathion
				Rice stink bugs	carbaryl, malathion, methyl parathion, phosphamidon

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Carrots (root crops)	7	15.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	
				Japanese beetle larvae	
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Garlic, Leeks, Onions & Shallots	7	15.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Leeks	7	4.0	Do not apply after seedling stage.	Cutworms	
Onions	7	5.0	Do not apply to green or spring onions.	Thrips	chlordane*, diazinon*, lindane*, malathion, methyl parathion*, parathion**, Phosdrin*
Shallots	7	3.0	Do not apply after seedling stage.		

* Onions only.
** Not on Leeks.

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	RECOMMENDED SUBSTITUTIONS
Horseradish	7	3.0	Do not use treated tops as food or feed.	Flea beetles	carbaryl
	7	15.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane
				Japanese beetle larvae	
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Parsnips	7	5.0	Do not use tops for food or feed.	Grasshoppers	carbaryl
Potatoes	Extended	15.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon
				Japanese beetle larvae	
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	
				Cutworms	
				Grasshoppers	
				Mole crickets	
Radishes	7	15.0	Single preplanting soil treatment or before edible parts begin to form.	Cutowrms	chlordane, diazinon
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	
				Cutworms	
				Grasshoppers	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Radishes: (field, greenhouse)	7	5.0	No time limitations.	Cutworms	carbaryl
				Foliage caterpillar	carbaryl, parathion
				Armyworm Salt marsh caterpillar Cabbage looper Grasshoppers Flea beetles Stink bugs Tortoise beetles Crickets Tomato russet mite	
Rutabagas	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets Cutworms Grasshoppers Mole crickets	
SOIL AND BARK TREATMENT: (non-root crops)					
Beans	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, parathion
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets Cutworms Grasshoppers Mole crickets	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Beans (green, lima, snap)	7	3 (dust only)	5 days. Do not feed treated vines, (forage) to dairy animals or animals being finished for slaughter.	Bean leaf roller	carbaryl, Guthion, methoxychlor, parathion
				Bean lycaenid	
				Corn earworm	carbaryl, methoxychlor, Phosdrin
				Cowpea curculio	carbaryl, methyl parathion, Thiodan
				Cutworms	methyl parathion, trichlorfon
				Darkling ground beetles	
				Flea beetles	methyl parathion
				Garden webworm	
				Grasshoppers	carbaryl, diazinon, Phosdrin
				Lygus bugs	Guthion, methyl parathion, phosphamidon, trichlorfon
				Pea weevil	
				Salt marsh caterpillar	Phosdrin, trichlorfon bait
				Serpentine leaf miner	diazinon, dimethoate, Guthion parathion, trichlorfon
				Thrips	parathion, phosphamidon, TDE, trichlorfon, Trithion
				Bean leaf skeletonizer Bean leaf beetle	pyrethrins
				Southern green stink bugs Loopers Cucumber beetles	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Beans (Cont.) (lima, green, and snap)				Cabbage looper Stink bugs Tortoise beetle Vegetable weevil Tobacco budworms	
Broccoli Brussels Sprouts	7	8.0	Do not apply after edible parts begin to form or within 30 days of harvest.	Armyworms	carbaryl, methyl parathion
				Cabbage looper	naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Imported cabbage worm	carbaryl, naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Thrips	lindane, methyl parathion, parathion
				Serpentine leaf miner	Phosdrin
				Cabbage caterpillar	malathion
				Cabbage worm	synergized pyrethrins
				Diamondback moth	synergized pyrethrins
				Corn earworms	diazinon
				Flea beetles	synergized pyrethrins
				Green peach aphid	diazinon
				Field Crickets Salt marsh caterpillar Grasshoppers Stink bugs Tortoise beetle Vegetable weevil Aphids	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Blackeyed peas	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane*, diazinon*
Cowpeas	7				
Peas	7			Japanese beetle larvae	chlordane*
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane*
				Cutworms	chlordane*
				Grasshoppers	chlordane*
*Cowpeas only.				Mole crickets	chlordane*
Broccoli	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon*, heptachlor, lindane, parathion.
Brussels Sprouts	7				
Collards	7				
Kohlrabi	7				
Kale	7			Japanese beetle larvae	chlordane
*Not on Kohlrabi.		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Cabbage	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	
				Japanese beetle larvae	chlordane
				Crickets	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cabbage (Cont.)	7	4.0	Do not apply after heads start to form.	Armyworms	carbaryl, methyl parathion, parathion
				Cabbage looper	naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Imported cabbage worm	carbaryl, naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Thrips	lindane, methyl parathion, parathion
				Serpentine leaf miner	Phosdrin
				Cabbage caterpillar	malathion
				Diamondback moth	synergized pyrethrins
				Corn earworm	diazinon
				Flea beetles	synergized pyrethrins
				Green peach aphid	diazinon
				Field crickets Salt marsh caterpillar Grasshoppers Stink bugs Tortoise beetles Vegetable weevil Aphids	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cauliflower	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
	7	8.0	Do not apply after edible parts begin to form or within 30 days of harvest.	Armyworms	carbaryl, methyl parathion, parathion
				Cabbage looper	naled, Guthion, Lannate, lindane, malathion, parathion, Phosdrin, Thiodan
				Imported cabbage worm	carbaryl, naled, Guthion, Lannate, Lindane, malathion, parathion, Phosdrin, Thiodan
				Thrips	lindane, methyl parathion, parathion
				Serpentine leaf miner	Phosdrin
				Cabbage caterpillar	malathion
				Imported cabbage worm	synergized pyrethrins
				Diamondback moth	synergized pyrethrins
				Corn earworm	diazinon
				Cutworms	Dylox bait

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cauliflower (Cont.)				Flea beetles	synergized pyrethrins
				Green peach aphid	diazinon
				Field crickets Salt marsh caterpillar Grasshoppers Stink bug Tortoise beetle Vegetable weevil Aphids	
Carrots	7	5.0	No time limitations.	Cutworms	methyl parathion, trichlorfon
				Grasshoppers	chlordane
				Flea beetles	methyl parathion
				Lygus bugs	trichlorfon
				Armyworms Fall armyworm Vegetable weevil Carrot weevil	
Celery	7	5.0	Do not apply after plants start to bunch or after plants are half mature.	Cabbage worms	lindane, malathion, parathion, Phosdrin, Thiodan
				Celery leaf tier	lindane, parathion, pyrethrins
				Cutworms	lindane, Phosdrin
				Fall armyworms	naled
				Serpentine leaf miner	Phosdrin
				Thrips Vegetable weevil	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Celery (Cont.)				Leaf miner	parathion
				Imported cabbage worm	
				Green peach aphid	synergized pyrethrins, Thiodan
				Loopers Armyworms	
	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon, lindane, parathion
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Corn	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	diazinon
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Cucumbers	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	diazinon, lindane
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Eggplant	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon, lindane
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	aldrin, chlordane
				Mole crickets	chlordane
Peanuts	7	25.0	Apply as a preplanting soil treatment or before edible parts begin to form. Single application.	Cutworms	diazinon
	7	25.0	Single soil application only. Do not apply after first cultivation.	Southern corn-rootworm	phorate, diazinon

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Peanuts (Cont.)	7	6.0	Do not feed treated forage to dairy animals or animals being finished for slaughter.	Corn earworm	carbaryl
				Cutworms	diazinon
				Flea hopper	
				Green clover worm	carbaryl
				Leaf hoppers	carbaryl, methoxychlor, malathion
				Leaf worms	carbaryl
				Red-necked peanut worm	parathion
				Southern green stink bug	carbaryl
				Thrips	carbaryl, malathion, parathion
				Velvet bean caterpillar	carbaryl, methoxychlor
				Fall armyworm	carbaryl, methoxychlor, parathion
Okra	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Peppers Pimentos	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon, heptachlor, lindane
				Japanese beetle larvae	chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Spinach	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon
				Japanese beetle larvae	
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane
Tomatoes	7	25.0	Single preplanting soil treatment or before edible parts begin to form.	Cutworms	chlordane, diazinon, heptachlor, lindane
				Japanese beetle larvae	parathion. chlordane
		2.5	Wet or dry bait formulations. Do not apply when edible parts are present, unless dosage is within limits of other applications of this insecticide.	Crickets	chlordane
				Cutworms	chlordane
				Grasshoppers	chlordane
				Mole crickets	chlordane

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
ANIMALS:					
Beef cattle (dip)	7 (in fat)	0.6% (in water)	Dip. Do not apply within 28 days of slaughter.	Hornfly	Delnav, coumaphos, lindane methoxychlor, malathion, ronnel
				Gnats	coumaphos, Delnav, lindane, methoxychlor, malathion, rotenone
				Mosquito	
				Sarcoptic mange	lindane, malathion, rotenone
				Screw worm*	coumaphos, lindane
				Spinose ear tick	
				Ticks	Delnav, coumaphos, lindane
				Scabies Chorioptic mites Psoroptic mites	
*With other ingredients.					
Beef cattle (spray)	7 (in fat)	0.6% (in water)	Spray. Do not apply within 28 days of slaughter.	Gnats	dichlorvos
				Hornfly	lindane, methoxychlor, crufomate, malathion, ronnel, synergized pyretarins
				Lice	crotoxyphos, coumaphos, Delnav, fenthion, lindane, malathion methoxychlor, crufomate, rotenone
				Mosquito	dichlorvos

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Beef cattle (spray)				Sarcoptic mange	lindane, malathion, rotenone
				Screw worm*	coumaphos, lindane, ronnel
				Spinose ear tick	lindane, malathion, ronnel, synergized pyrethrins
				Ticks	Delnav, carbaryl, coumaphos, lindane, malathion
				Scabies Face fly Chorioptic mites Psoroptic mites	
*With other ingredients.					
Beef cattle (dust)	7 (in fat)	5.0% (dust)	Dust animals thoroughly. Do not apply within 28 days of slaughter.	Lice	lindane, methoxychlor, synergized pyrethrins, rotenone
Beef cattle (dust bag)	7 (in fat)	5.0% (dust)	Applied in dust bags, with other ingredients. Do not permit animals access to dust bags for 30 days prior to slaughter.	Horn fly	coumaphos, crotoxyphos, carbaryl, Delnav, lindane, methoxychlor
Beef cattle (backrubber)	7 (in fat)	8.0% (in oil)	Apply by backrubbers. Do not permit animals access to treatment within 24 days of slaughter.	Face fly Gnats	coumaphos
				Horn fly Lice Mosquito Ticks	coumaphos, crotoxyphos, Delnav, fenthion, lindane, malathion, methoxychlor, ronnel

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Beef cattle	7 (in fat)	5.0% (in oil)	Apply sparingly by brush or sponge. Wet tips of the hair. Do not soak the hide.		
Beef cattle	7 (in fat)	2.0%	Apply locally as screw-worm and ear tick treatment. Formulated in combination with other insecticides as smear or liquid.	Ear tick	coumaphos
				Screw-worm	coumaphos
Goats, Sheep (dip)	7	0.6%	Dip. Do not apply within 28 days of slaughter. Do not use on dairy goats.	Keds	coumaphos, Delnav, lindane, malathion, ronnel
				Fleece worms	coumaphos, Delnav, lindane, ronnel
				Lice	coumaphos, crotoxyphos, Delnav, lindane, malathion, methoxychlor, ronnel, crufomate
				Psoroptic mange	
				Screw-worm	coumaphos, lindane, ronnel
				Ticks	coumaphos, Delnav, lindane, Malathion, ronnel
				Scabies Chorioptic mites Psoroptic mites	
Goats, Sheep (spray)	7 (in fat)	0.6% (in water)	Spray. Do not apply within 28 days of slaughter. Do not use on dairy goats.	Fleece worm	coumaphos, Delnav, lindane, ronnel

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Goats, Sheep (Spray). (Cont.).	7 (in fat)	0.6% (in water)	Spray. Do not apply within 28 days of slaughter. Do not use on dairy goats.	Keds	coumaphos, Delnav, diazinon, lindane, malathion, ronnel, rotenone, synergizedpyrethrins
				Lice	coumaphos,carbaryl, crotoxyphos, Delnav,diazinon, lindane, malathion, methoxy-chlor, ronnel, cruformate
				Psoroptic mange	
				Screw-worm	coumaphos, lindane, ronnel
				Ticks	coumaphos, carbary, Delnav, crotoxyphos, lindane, malathion, ronnel
				Scabies Chorioptic mites Psoroptic mites	
Goats, Sheep (dust)	7 (in fat)	5.0% (dust)	Dust animals thoroughly. Do not apply within 28 days of slaughter.	Keds	coumaphos, diazinon, lindane, malathion
				Lice	coumaphos, lindane,malathion
				Ticks	coumaphos,lindane, malathion
Goats, Sheep	7	2.0%	Apply locally as screw-worm and fleece worm treat-ment. Formulated in combi-nation with other insecticides.	Fleece worm	Delnav
				Screw-worm	Delnav
Swine	7 (in fat)	0.6% (in water)	Dip or spray. Do not apply within 28 days of slaughter.	Lice	carbaryl*,coumaphos*, crotoxyphos*, Delnav, lindane, malathion,methoxychlor,ronnel, rotenone,synergized pyrethrins

*Not for dip.

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Swine				Sarcoptic mange	malathion, synergized pyrethrins
				Ticks Chorioptic mites Psoroptic mites	
Swine (dust)		5.0% (dust)	Dust animals thoroughly Do not apply within 28 days of slaughter.	Lice Sarcoptic mange	lindane, malathion, rotenone, synergized pyrethrins
Swine (backrubber)		8.0%	Apply by rubbing devices Do not permit animals access to this treatment within 28 days of slaughter.	Lice	malathion
AGRICULTURAL PREMISES:					
Barns Sheds Animals Shelters Fences Other Farm Buildings (excluding dairy barns, milk rooms, and poultry houses)	NF	400 mg/sq. ft.	Dust or spray. Apply to interior and exterior surfaces, also exterior of dairy barns.	Flies	
Grain bins and Grain elevators	NF	400 mg/sq. ft.	Apply to interior and exterior surface as a residual treatment. Do not apply to or contaminate grain or other foods.	Grain and Cereal Pests	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED FORMULATIONS
Grass (range only)	7 (in fat of meat from cattle, goats, hogs, horses, and sheep)	1.5	Only one application per season.	Armyworm	methyl parathion, parathion
				Chiggers	
				Corn-earworm	
				Cutworms	parathion
	Forage Extended	2.0 (in water)	Do not apply more than once per season. Do not graze dairy animals in treated fields. Do not graze meat animals in treated fields within 6 weeks of slaughter. Do not apply to forage to be sold commercially or shipped interstate.	Grasshoppers	carbaryl, chlordane, diazinon, naled, malathion, methoxychlor, methyl parathion
				Webworms	parathion
				Flea beetles	
				Leafhoppers	
				Lygus bugs	
				Thrips	
				Looping grassworm complex	
				Vagabond crambug	
				New Mexico range caterpillar	
				Spittle bugs	
Lawn and Turf	NF	5	Keep off until dry or well watered in.	Japanese beetle larvae	carbaryl, chlordane, heptachlor, milky spore disease
				Sod webworm	carbaryl, chlordane, diazinon, chlorpyrifos, ethion, heptachlor
				Chiggers	allethrin
				Ticks	diazinon
				Grasshoppers	diazinon
				Earwigs	
				Fall armyworm	
				Chinch bugs	
				Crickets	
				Cutworms	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Ditch banks Field borders Roadsides Vacant lands				Chiggers	chlordane
				Crickets Grasshoppers	carbaryl, chlordane, naled, heptachlor, malathion
				Ticks	chlordane, Gardona
				Cutworms	
Flower garden plants, Ornamentals, and Shade trees	NF	5 or 5 lbs. per 100 gals. water-full coverage sprays.		Bagworm	Bidrin, carbaryl, chlordane, diazinon, dimethoate, malathion, parathion, trichlorfon, Trithion
				Blister beetles	carbaryl, Meta-systox R
				Box elder bug	carbaryl, chlordane
				Cabbage looper	Zectran
				Canker worms	carbaryl, methoxychlor, TDE
				Catalpa worm	
				Cyclamen mite	diazinon, endrin, Thiodan
				Elm leaf beetle	carbaryl, chlordane, Di-Syston, Meta-systox-R, methoxychlor, TDE, Trithion
				Fall armyworm	chlordane, methoxychlor
				Fall webworm	chlordane, diazinon, methoxychlor, trichlorfon
				Froghopper	
				Gladiolus Thrips	malathion

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	RECOMMENDED FORMULATION
Flower garden Plants Ornamentals and Shade Trees (CONT.)				Lace bugs	allethrin, Bidrin, carbaryl, chlordane, diazinon, dimethoate, Di-Syston*, Cathion, malathion, parathion, synergized pyrethrins, TDE
				Maple worm	
				May beetles	chlordane, methoxychlor
				Mimosa webworm	Bidrin, carbaryl, diazinon
*Systemic soil application				Spiny elm caterpillar	Zectran
				Pecan weevil	EPN
				Sawfly (on pine)	Bidrin, Zectran
				Tent caterpillars	carbaryl, diazinon, Di-Syston* malathion, methoxychlor, phosphamidon
				Walnut caterpillar	
				Red spiders	naled
				Thrips	allethrin
				Leafhopper	
				Green striped maple worm	
				Grasshoppers	
				Crickets	
				Leafrollers	
*Systemic soil application				Cutworms	

CROP OR USE	TOLERANCE (ppm or non-food)	DOSAGE (lbs. per Acre)	LIMITATIONS	PESTS	REGISTERED SUBSTITUTES
Household and Commercial	NF	5% or 6% (in oil or water)	Spot residual applications. Protect food from exposure.	Ants	propoxur, chlordane, diazinon, heptachlor, lindane, malathion, pyrethrum powder, ronnel
				Flies	propoxur, chlordane, diazinon, heptachlor, lindane, malathion, ronnel
				Gnats	chlordane, diazinon, heptachlor lindane, malathion, ronnel
				Mosquitoes	propoxur, chlordane, heptachlor, lindane, malathion, ronnel
				Roaches	propoxur, chlordane, diazinon, heptachlor, lindane, malathion, Pyrethrin powder, ronnel
				Silverfish	propoxur, chlordane, diazinon, heptachlor, lindane, malathion, ronnel
Mothproofing	NF	5% in oil	Thoroughly moisten out. Do not wet woolens to be protected. Protection for one storage season. Do not treat furs or light colored items subject to staining. Repeat after laundering or dryecleaning.	Clothes moth	methoxychlor, Perthane, Dirobane

Table VI.B. Strobane:

This chlorinated hydrocarbon pesticide, which is produced by Tenneco Company, is very similar to toxaphene and is categorized in the ingredients statement labeling as terpene polychlorinates with 65 percent of chlorine. The starting material for this pesticide consists of terpene polypinene and related terpenes. This pesticide came into some prominence in the middle to late 1960's, primarily as a pesticide for use on cotton, but to some extent as a mothproofer and household insecticide.

The pesticidal value of these products so far as they have been investigated, appear to be closely related to those of toxaphene. The principal registered applications of Strobane are on cotton and are covered by a 5 parts per million tolerance on cotton seed for both Strobane and toxaphene. In addition, Strobane at the level of 5 percent has been registered as a mothproofer for the treatment of woolens and fabrics subject to damage by fabric pests. It is also used at the 2 percent level as an ingredient in household insecticides in combination with synergized pyrethrin and other ingredients. In addition, it is used as a residual ingredient in commercial premises outside of the edible products area. Wet spray application may contain up to 2 percent Strobane.

Table VI.B. contains registered uses, tolerances and registered substitutes for Strobane.

TABLE VI.B.

REGISTERED USES OF STROBANE

Crop or Site of Application	Tolerance (ppm or non-food)	Dosage lbs. per Acre or Concentration	Limitations	Pests	Registered Substitutes
Cotton	5	1-4 (Dust or Spray)	Usually mixed with DDT, methyl parathion or both. Do not feed gin waste to livestock. Do not graze dairy animals or animals being fattened for slaughter.	Boll weevil Boll worm Pink boll worm Thrips Leaf worm Grasshoppers Flea hoppers Aphids Certain mites Cabbage loopers Cutworms Fall army worm Lygus bugs	toxaphene methyl parathion
HOUSEHOLD AND COMMERCIAL PREMISES:	NF	2% in liquid form and and pressurized dispensers.	Usually in combination with synergized pyrethrin or other ingredients as space and contact sprays both indoors and outdoors. Food should always be protected from chemical contaminations.	Flies Mosquitoes Other small flying insects, roaches, ants, spiders, silverfish, bed bugs, clothes moths, carpet beetles, scorpions, fleas, earwigs, hornets, wasps, fly maggots, exposed stages of various pantry pests including various weevils, beetles, and moths, infesting grains and dry cereal products.	synergized pyrethrins, malathion, ronnel, dichlorvos (DDVP)

Crop or Site of Application	Tolerance (ppm or non-food)	Dosage lbs. per Acre or Concentration	Limitations	Pests	Registered Substitutes
HOUSEHOLD AND COMMERCIAL USE:	NF	3% in water emulsion form or 5% in pressurized form.	Garbage can spray. Apply thoroughly and frequently.	Fly maggots, Flies	malathion, diazinon, chlordane
	NF	0.5%-2% emulsion in water or in oil with other ingredients.	Commercial or industrial use only. General residual applications both indoors and outdoors. Not for use in the exposed food areas of food processing plants. However, all food should be protected in all cases.	Ants, Roaches, Exposed stages of cereal grain pests, silverfish, mites, fleas and ticks.	
Woolens, Drapes, Blankets, Upholstered furniture, Garments, Rugs, Closets and other storage containers and receptacles.		5% in liguid or in pressurized dispensers.	Thoroughly moisten but do not soak or wet articles to be protected. Apply uniform mist spray over article to be protected especially along seams and folds. The protection will last about one year but application should be reapplied after laundering or drycleaning. Pressurized dispensers or sprayers should be held about 18" from spraying surface. The purpose is to deposit approximately 0.35% of Strobane in article to be protected based on the dry weight of woolens. Do not treat furs or any delicate fabric subject to staining.	Clothes moths, Carpet beetles, and other fabric pests.	toxaphene, methoxychlor, perthane

Crop or Site of Application	Tolerance (ppm or non-food)	Dosage lbs. per Acre or Concentration	Limitation	Pests	Registered Substitutes
Embalming: Use on Cadavers.	NF	3% in pressurized dispensers.	Spray in the body openings to saturate. Do not use as a space spray. Do not treat clothing.	Flies Fly maggots	